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SURVEILLANCE REPORT. STAGE I DISSECTED MOTORS. PHASE VII. PROPE--ETC(U)
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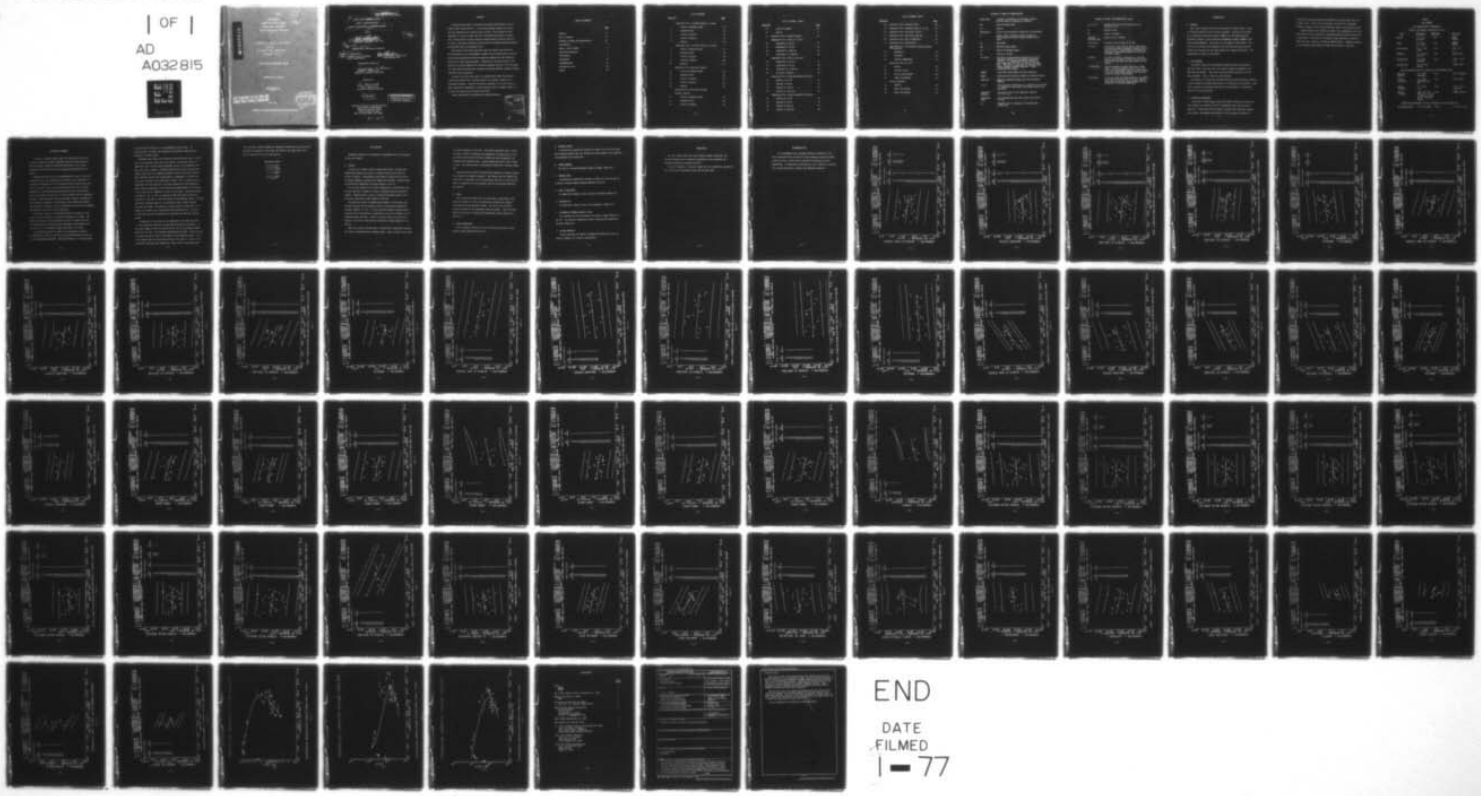

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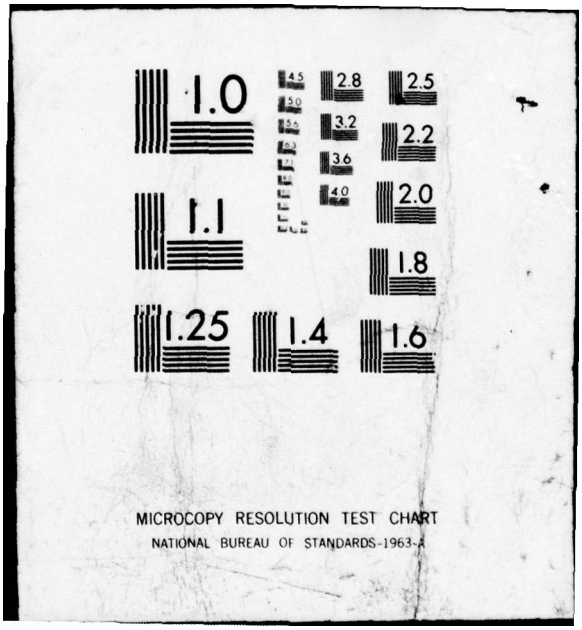
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

HEADQUARTERS
OGDEN AIR LOGISTICS CENTER
UNITED STATES AIR FORCE
HILL AIR FORCE BASE, UTAH 84406

SURVEILLANCE REPORT
STAGE I
DISSECTED MOTORS
PHASE VIII

PROPELLANT AND COMPONENT TESTING

PROPELLANT LAB SECTION

MANCP REPORT NR
358(76)

OCT 1976

(14) MANCP [redacted]-358(76)
MMEMP PROJECT M72632 5MP116P

(6) SURVEILLANCE [redacted] REPORT .
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and

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ABSTRACT

Testing was performed to determine the useful shelf/service life for LGM-30 Stage I Rocket Motors. A three year storage program for propellant and components was started in May of 1961. This program was then extended to a ten year study and later continued indefinitely to assure that a deterioration in motor physical characteristics could be detected in time to take some corrective actions before the weapon system performance deteriorated below an acceptable level.

This report covers only propellant data and limited case bond data. The mal-function of an environmental chamber and the inadvertant burning of motors during dissection destroyed component samples that had originally been part of this testing program. Dissection of selected motors in the future will provide samples for continued component testing. Test specimens for this reporting period were obtained from motors STM-012, 0012099, 0012199 and UP7775 block propellant.

The data from this test period are combined with data from previous testing and entered into the G085 computer for storage, analysis, and regression analysis. From the statistical analysis of all data tested to date, significant degradation of the propellant does not appear likely for at least two years past the oldest data point.

Future testing will be conducted on dissected motors.

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GLOSSARY OF TERMS AND ABBREVIATIONS

Aging Trend	A change in properties or performance resulting from aging of material or component
CSA	Cross Sectional Area
DB	Dogbone
Degradation	Gradual deterioration of properties or performance
E	Modulus (psi), defined as stress divided by strain along the initial linear portion of the curve.
EB	End Bonded
EGL	Effective Gage Length
em	Strain at maximum stress
er	Strain at rupture
"F" ratio	The ratio of the variance accounted for by the regression function to the random unexplained variance. The regression function having the most significant "F" ratio is used for plotting data. The ratio is also used in detecting significant changes in random variation between succeeding time points
JANNAF	Joint Army, Navy, NASA, Air Force Committee
MANCP	Propellant Lab Section at Ogden Air Logistics Center
Ogden ALC	Ogden Air Logistics Center, Air Force Logistics Command
r or R	The Correlation Coefficient is a measure of the degree of closeness of the linear relationship between two variables
Regression Equation	The general form of the regression equation is $Y = a + bx$
Regression Line	Line representing mean test values with respect to time
S_b	Standard error of estimate of the regression coefficient

GLOSSARY OF TERMS AND ABBREVIATIONS (cont)

S_e or $S_{Y.X}$	Standard deviation of the data about the regression line
Sm	Maximum Stress
Sr	Stress at rupture
Standard Deviation (S_y)	Square root of variance
Strain Rate	Crosshead speed divided by the EGL
"t" test	A statistical test used to detect significant differences between a measured parameter and an expected value of the parameter (determines if regression slope differs from zero at the 95% confidence level)
Variance	The sum of squares of deviations of the test results from the mean of the series after division by one less than the total number of test results
3 Sigma Band	The area between the upper and lower 3 sigma limit. It can be expected that 99.73% of the inventory represented by the test samples would fall within this range assuming that the population is normally distributed.
90-90 Band	It can be stated with 90% confidence that 90% of the inventory represented by the test samples would fall within this range assuming that the population is normally distributed

INTRODUCTION

A. PURPOSE:

This report contains test data from samples of LGM-30 Stage I, Wings I-V TP-H1011 propellant and case bond specimens. Testing was performed by the Propellant Laboratory Section (MANCP) for the Engineering and Reliability Branch of the Airmunitions Management Division (MMWRM) under Project M72632-5MP116P. This report is the eighth in this series. Data from this test period and propellant test data from the seven previous reports were entered into the G085 computer for regression analysis. The regressions are shown in this report.

B. TEST PROGRAM:

The LGM-30 Laboratory and Component Program includes the testing of materials used in the main case, aft closure, ignition assemblies, and main grain propellant. This report covers TP-H1011 propellant and case bond specimens. Table I shows the test program.

Propellant for testing was obtained from three dissected motors, STM-012, a motor prepared by Thiokol specifically for dissection, S/N 0012099, a SLIM motor, and motor S/N 0012199 selected from the inventory for dissection and UP-7775 block propellant.

C. HISTORICAL BACKGROUND:

In may 1961, Thiokol began a three year LGM-30 laboratory storage and test program to determine the rate of degradation with age for Stage I materials. During June 1962 and again in August 1963, additional samples were stored. New samples were added in July and August 1964 when the

surveillance testing program was extended to ten years (Test Plan 0717-62-0967, 53-8). Carton block propellant, batch UP-7775, containing TP-H1011 propellant cast in March 1962 was added to the program in 1964.

Samples added to the inventory in 1964 were considered to be a new population, but were combined in regression analysis with the three dissected motors. The history of testing of these materials is found in MQQP Report Nrs. 108A(67), 144(68) and MAGCP 208(71). Physical transfer of the specimens from Thiokol to Ogden ALC was made in June 1967.

TABLE I

TEST PROGRAM

All Temperatures in Fahrenheit

STM-012, SN 0012099, SN 0012199, UP-7775

Test	Conditions	Spec/Cond	Spec Conf
Tensile	77°, 2.0 & 20 in/min	5 ea	JANNAF Dogbone
Creep	77°, 10 & 12 lb load	2 ea	JANNAF Dogbone
Stress Relax	77°, 3 & 5% strain	3 ea	1/2" x 1/2" x 4"
Hardness	77°, initial & 10 sec	5 ea	Dogbone ends
Burning Rate	77°, 500 & 1,000 psi	5 ea	.156" x .156" x 5"
Ignitability	77°, 168 cal/ cm^2/sec		0.050" wafer
UP7775 propellant was not included in the following tests:			
High Rate Tensile	77°, 1,000 in/in/min	5 ea	3/4" GL Dogbone
Triaxial High Rate	77°, 1,000 in/in/min, 600 psi	2 ea	3/4" GL Rail
Dynamic Response	77°, 70 gm ct wt	2 ea	3.3" x .33" x .690 disc
Failure Envelope	Temp: -50, -20° 10°, 40°, 77°, 130° & 180°F at a rate of 0.2, 2.0 & 20 in/min	3 ea	JANNAF Dogbone
STM-012 and SN 0012199 only were included in the following test:			
Case Bond Tensile	77°, 0.2 in/min	10 ea	1" x 5/8" x 3/4"

STATISTICAL APPROACH

In order to determine aging trends for shelf/service life predictions, available TP-H1011 propellant data from three dissected motors (STM-012, 0012099 and 0012199) and TP-H1011 block carton propellant from batch UP-7775 were statistically analyzed and reported.

Although batch UP-7775 is not representative of any of the three dissected motors, the propellant was provided to the laboratory to increase the extended life of the dissected motor program from three years to 10 years. Due to insufficient data from UP-7775 testing, compatability testing between dissected motor data and block data were not performed individually, but were combined into one regression analysis. When sufficient data are available, separate analyses will be performed to determine if differences exist between the original dissected Motor (STM-012), the two additional dissected motors (0012099 and 0012199), and UP-7775 carton propellant.

The primary reason for performing statistical analysis on test data is for the detection of propellant changes due to aging. The method of analysis called regression was used to examine data and to draw meaningful conclusions about dependency relationships that may exist i.e., relationship between age versus test results.

In selecting the best fit model for the regression equation, six models were fitted to the data (see regression models at the end of this statistical approach). The linear model $Y = a + bX$ was found

to be the best fit model for the regressions in this report. By using the best fit model, the regression line becomes a more accurate predictor of future trends.

Individual data points from different time periods were used to establish a least squares trend line for the data. The variance about the regression line, obtained using individual values of the dependent variable, was used to compute a tolerance interval such that at the 90% confidence level 90% of the sample distribution falls within this interval. This tolerance interval was extrapolated to a maximum of 24 months into the future from age of the oldest motor tested. The 't' values and the significance of this statistic, which are reported for each regression model, give an indication of the "statistical significance" of the slope of the trend line as compared to a line of zero slope. Data were plotted by computer. The 'y' axis is computed so that the values at one inch intervals are peculiar to the data spread of the parameter tested. Plotted data points represent means at the particular ages at which testing occurred. The number of specimens at each age point is indicated on the sample size summary sheet accompanying each regression plot. Variance at each test age can be determined by consulting the G085 data storage system.

A comparison of the slopes of the regression trend lines and their Y - axis intercepts found in the regression equation was performed. Of the tests common to this test period and the last test performed (MANCP Report Nr 341 (76)), the following observations were made: There has been an average increase of 22% in the number of total samples tested. 16.7% of the aging trend lines have become flatter or closer to a line of zero slope which indicates less change due to age; 28.6% of the aging trend

lines show more change although the changes are gradual and no operational problems are expected at this time; and 54.8% of the aging trend lines show no change from the last test period.

Regression Models

$$Y = a + b\ 1/x$$
$$Y = a + b\ \ln x$$
$$Y = a + b \log x$$
$$Y = a + b\sqrt[-2]{x}$$
$$Y = a + b\sqrt[3]{x}$$
$$Y = a + bx$$

TEST RESULTS

Regression analysis is the method of evaluation used in the analysis of the test results.

A. TENSILE:

Low rate (2.0 in/min) tensile testing data shows a statistically significant decrease for strain at maximum stress and no trend for strain at rupture. The maximum stress shows no trend with the stress at rupture showing a statistically significant decrease. Modulus shows a statistically significant increase (Figures 1 thru 5).

For low rate tensile at 20 in/min regressions; a statistically significant decrease is shown for strain at maximum stress and stress at rupture. Maximum stress, strain at rupture and modulus shows no statistically significant trend (Figures 6 thru 10).

The high rate strain at maximum stress shows a statistically significant decrease and the maximum stress a statistically significant increase (Figures 11 & 12). In both cases, the change is gradual which indicates that the propellant as measured by this test parameter is not changing rapidly with age. Strain at rupture, stress at rupture and modulus do not show a statistically significant change (Figures 13, 14 and 15).

High rate triaxial testing shows a statistically significant increase for strain at maximum stress, maximum stress, strain at rupture and stress

at rupture (Figures 16 thru 19). The strains regression show a rapid increase, however on examining the regression the sample size is still very small and the data from the 72 month test period appears to be weighting the regression line. Future testing may show a slope closer to zero. The modulus shows a statistically significant decrease (Figure 20).

Case bond tensile shows a statistically significant decrease (Figure 21), however, the change is gradual. The failure mode for STM-012 was 100% liner to propellant for five specimens, 50% liner to case and 50% liner to propellant for one specimen, and for one specimen 100% bonding failure.

B. CREEP:

Creep compliance using the 10 lb load shows a statistically significant decrease at 10 and 20 second and no significant change at one thousand and ten thousand seconds. For the 10 and 20 second results, the slope of the regression curve is gradual. The 12 lb load results do not show a statistically significant change (Figures 22 thru 29).

C. STRESS RELAXATION:

Stress relaxation modulus for both 3 and 5% strain shows no significant trends (Figures 30 thru 37).

D. CONSTANT STRAIN:

A statistically significant decrease is shown, but as with the High Rate Triaxial Tensile test the 72 month test data appears to be weighting the regression line (Figure 38).

E. SHORE HARDNESS:

The shore A ten second hardness shows no change (Figure 39).

F. BURNING RATE:

A statistically significant decrease is shown for both the 500 and 1,000 psi initial pressure testing (Figures 40 and 41).

G. HEAT OF EXPLOSION:

No significant change is seen for heat of explosion (Figure 42).

H. IGNITABILITY:

No significant change is seen in the regression (Figure 43).

I. DIFFERENTIAL THERMAL ANALYSIS (DTA):

The endotherm and first exotherm do not show a change (Figures 44 and 45). The ignition temperature shows a statistically significant increase (Figure 46).

J. FAILURE ENVELOPE:

Failure envelopes for STM-012, 0012099 and 0012199 test data are shown in Figures 51, 52 and 53 respectively.

CONCLUSIONS

The test results show that under present storage conditions, the physical/mechanical and combustion properties of the propellant are remaining relatively unchanged with age.

From this analysis, it does not appear that any significant degredation will occur in the propellant within the next two years.

RECOMMENDATIONS

It is recommended that continued testing be conducted on the three dissected motors and UP-7775 block propellant presently being tested and also on those motors selected for testing by Service Engineering. On those motors selected for future dissection, testing will include propellant, casebond and component materials.

Y = ((+2.4181996E-01) + (-1.0545632E-04) * X)

F = +6.6005698E+00 SIGNIFICANCE OF F = SIGNIFICANT σ_1 = +2.3688960E-02

R = -1.7219779E-01 SIGNIFICANCE OF R = SIGNIFICANT S_a = +4.1047046E-05

t = +2.5691574E+00 SIGNIFICANCE OF t = SIGNIFICANT S_t = +2.3389058E-02

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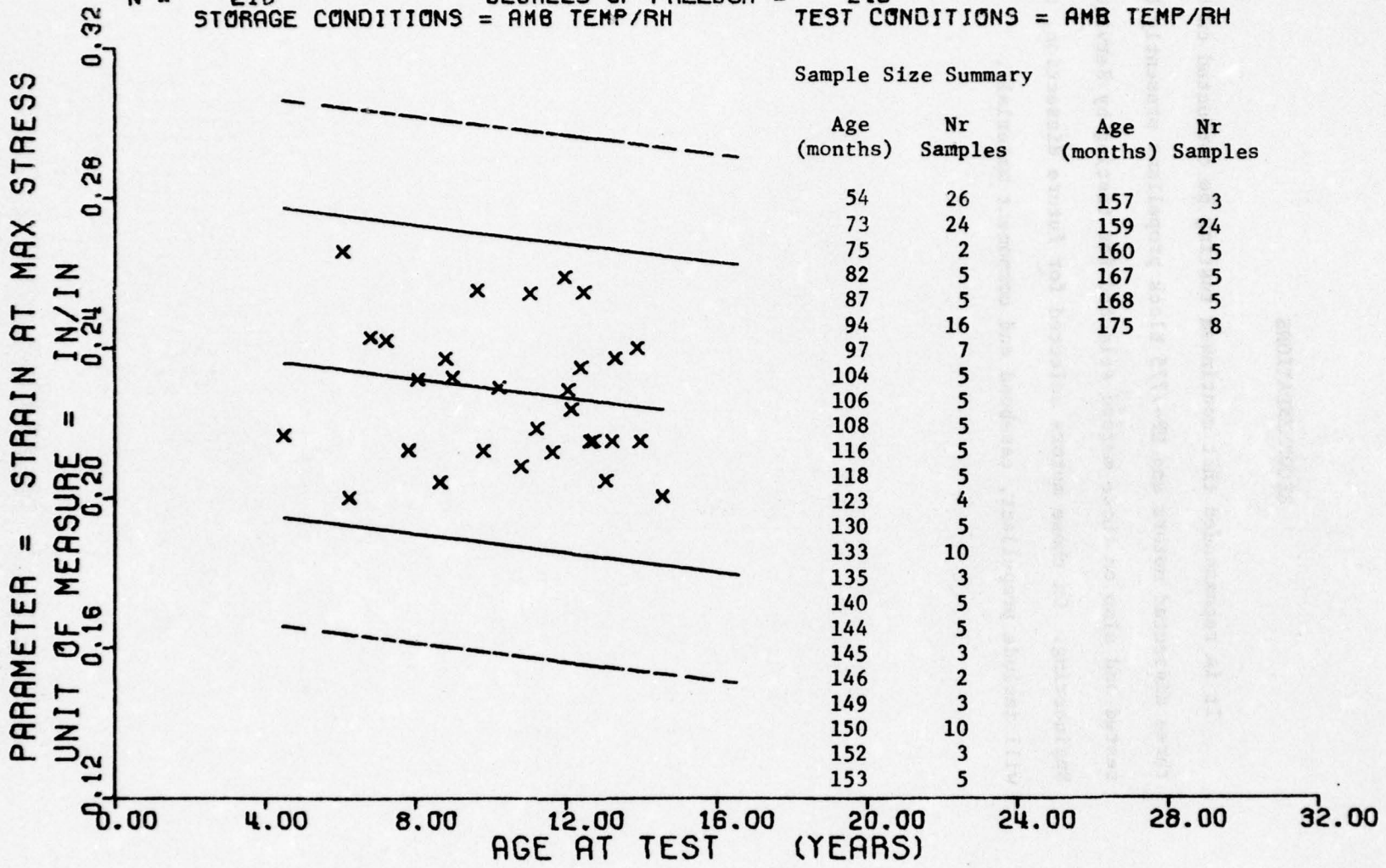
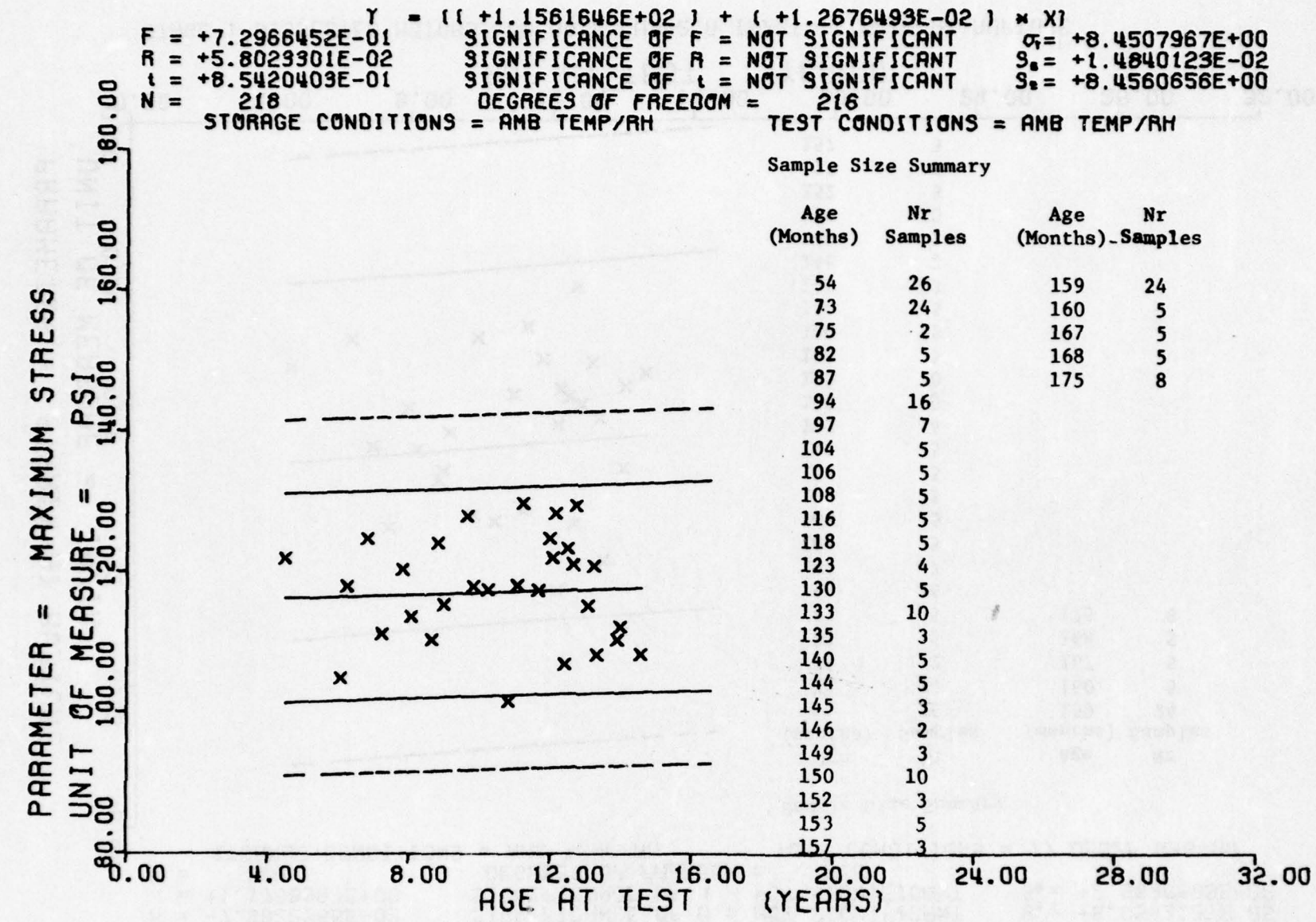


Sample Size Summary

Age (months)	Nr Samples	Age (months)	Nr Samples
54	26	157	3
73	24	159	24
75	2	160	5
82	5	167	5
87	5	168	5
94	16	175	8
97	7		
104	5		
106	5		
108	5		
116	5		
118	5		
123	4		
130	5		
133	10		
135	3		
140	5		
144	5		
145	3		
146	2		
149	3		
150	10		
152	3		
153	5		

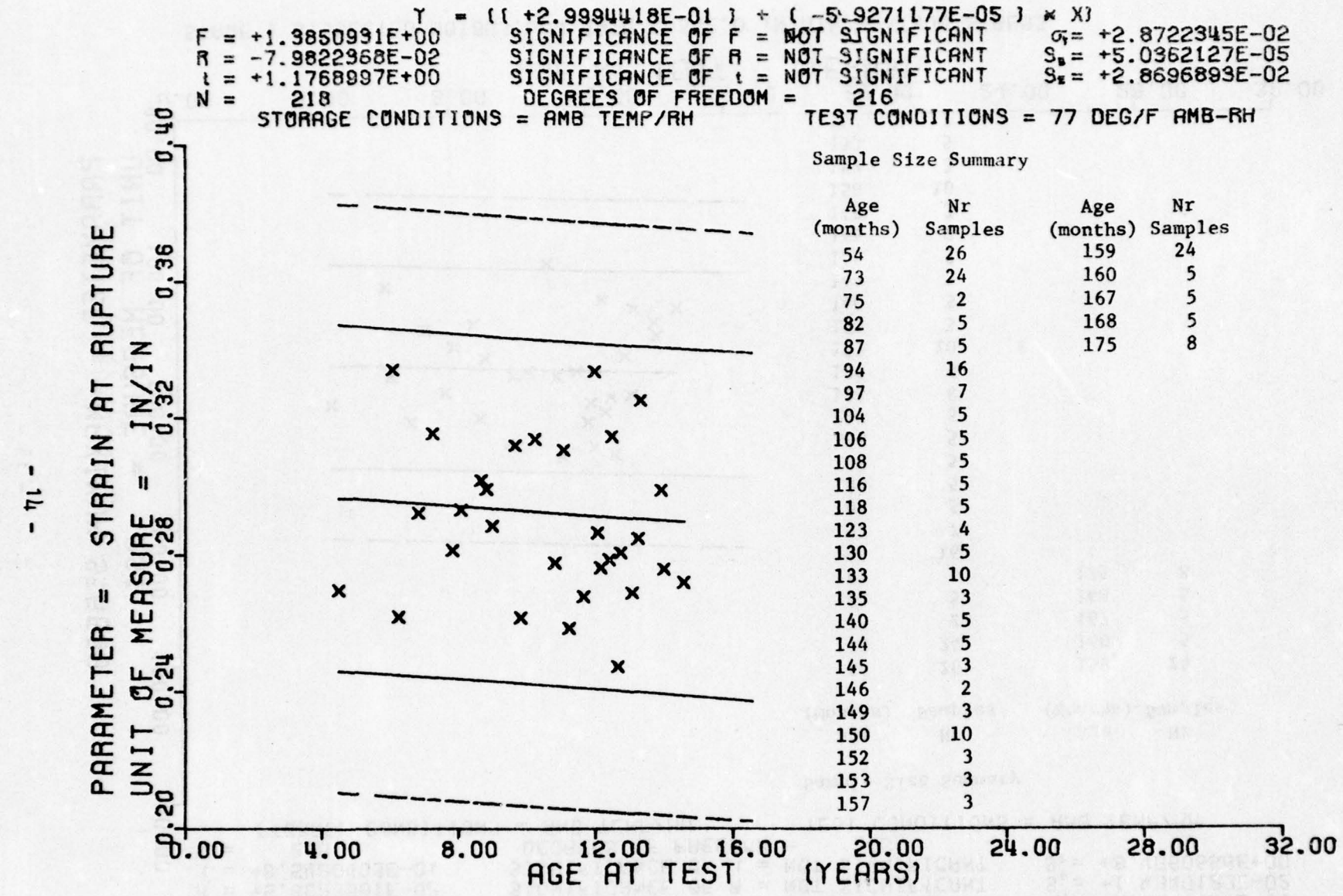
STAGE 1 DISSECTED MOTORS, LOW RATE CHS=2.0 IN/MIN, STRAIN MAX STRESS

Figure 1



STAGE 1 DISSECTED MOTORS,LOW RATE CHS=2.0 IN/MIN,MAXIMUM STRESS

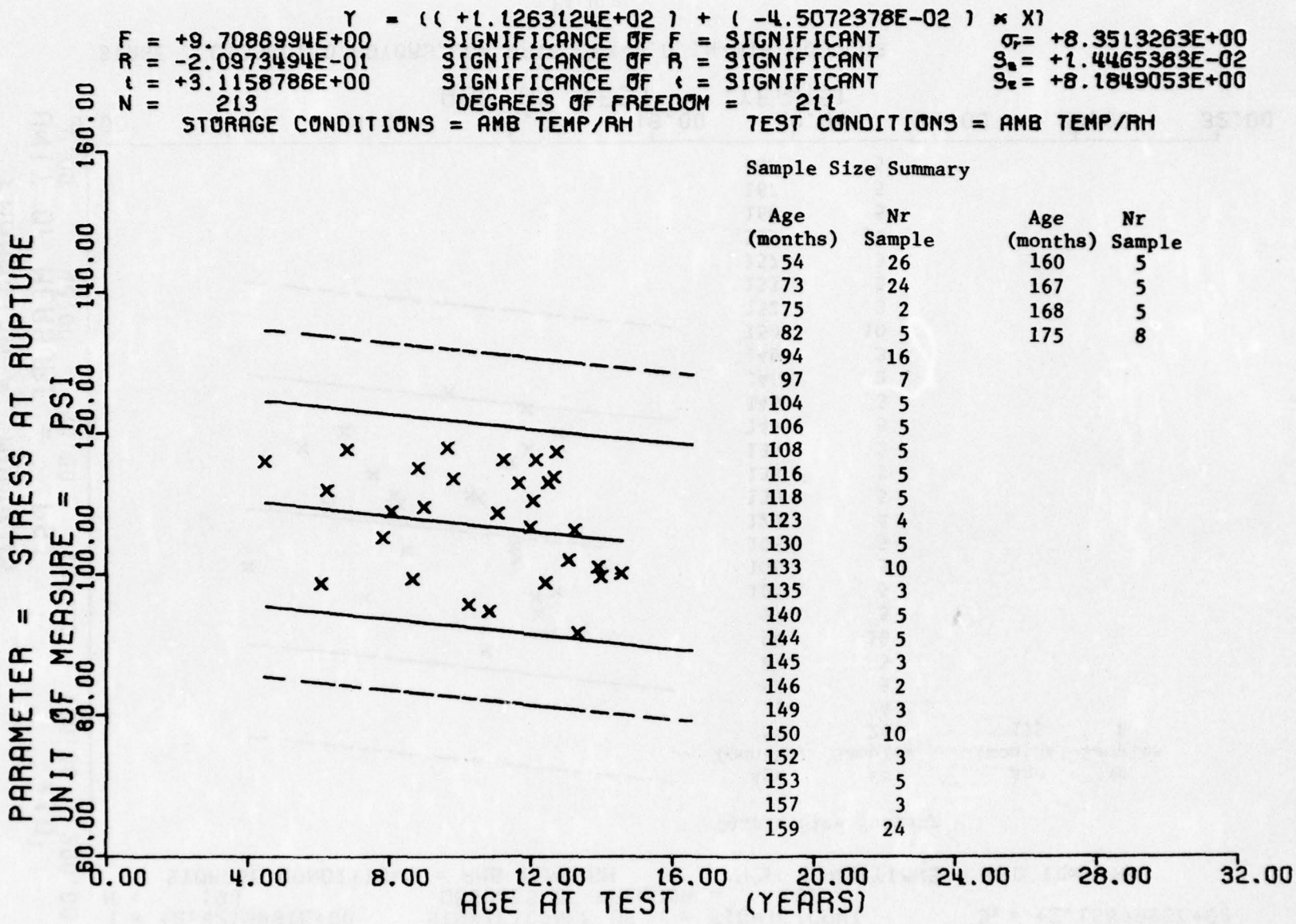
Figure 2



Sample Size Summary

Age (months)	Nr Samples	Age (months)	Nr Samples
54	26	159	24
73	24	160	5
75	2	167	5
82	5	168	5
87	5	175	8
94	16		
97	7		
104	5		
106	5		
108	5		
116	5		
118	5		
123	4		
130	5		
133	10		
135	3		
140	5		
144	5		
145	3		
146	2		
149	3		
150	10		
152	3		
153	3		
157	3		

Figure 3

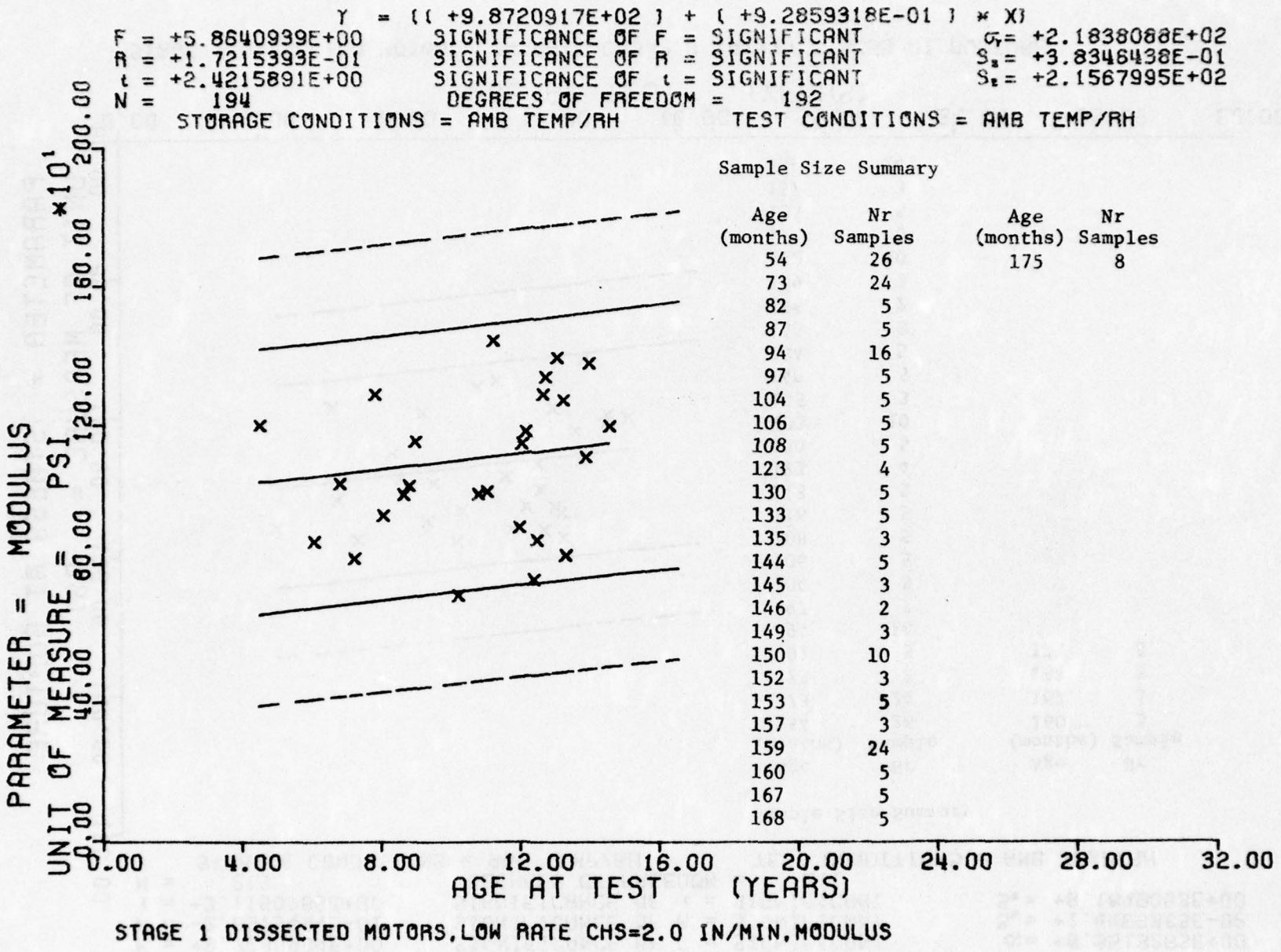


Sample Size Summary

Age (months)	Nr Sample	Age (months)	Nr Sample
54	26	160	5
73	24	167	5
75	2	168	5
82	5	175	8
94	16		
97	7		
104	5		
106	5		
108	5		
116	5		
118	5		
123	4		
130	5		
133	10		
135	3		
140	5		
144	5		
145	3		
146	2		
149	3		
150	10		
152	3		
153	5		
157	3		
159	24		

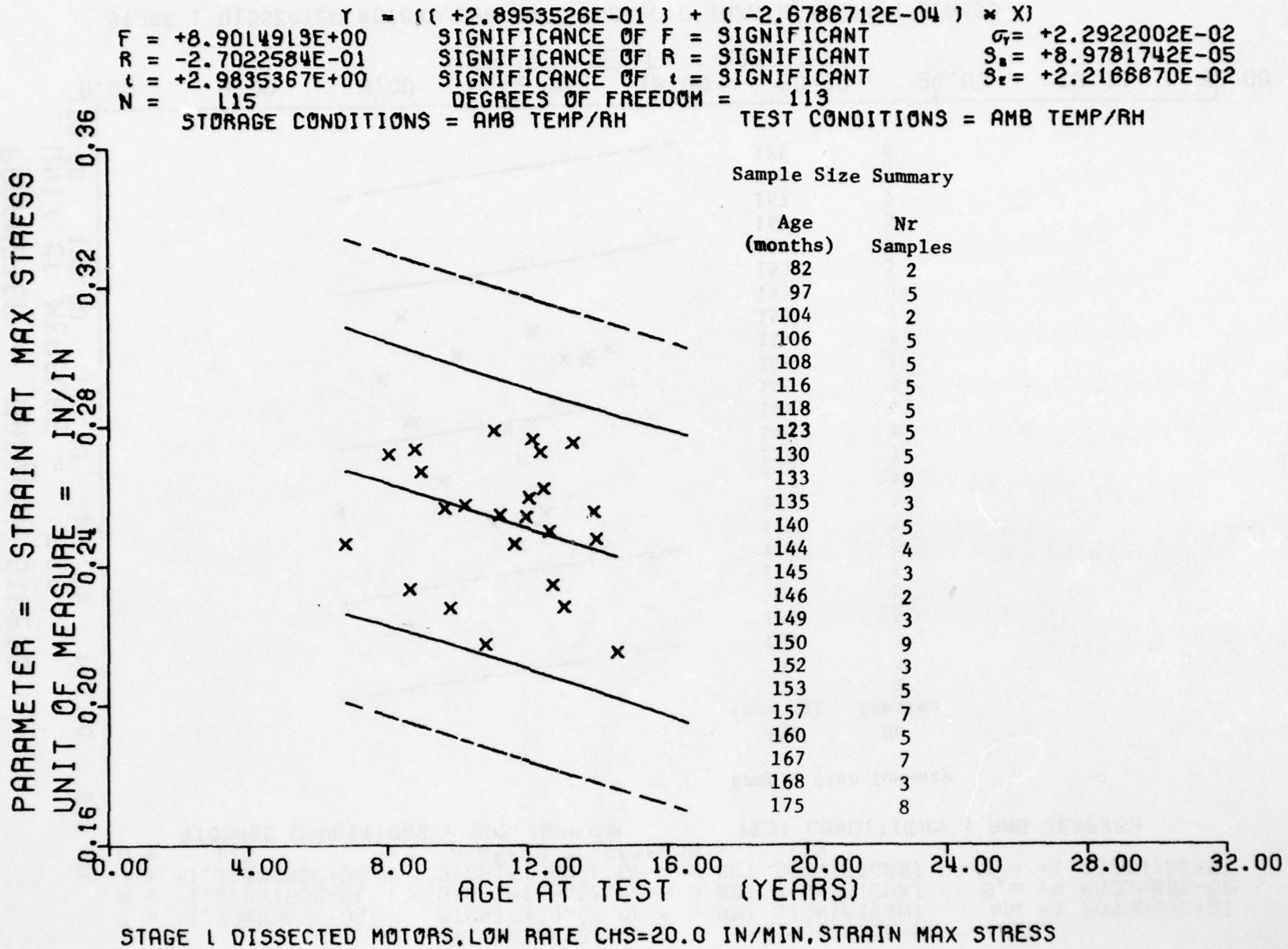
STAGE 1 DISSECTED MOTORS,LOW RATE CHS=2.0 IN/MIN,STRESS AT RUPTURE

Figure 4



STAGE 1 DISSECTED MOTORS,LOW RATE CHS=2.0 IN/MIN,MODULUS

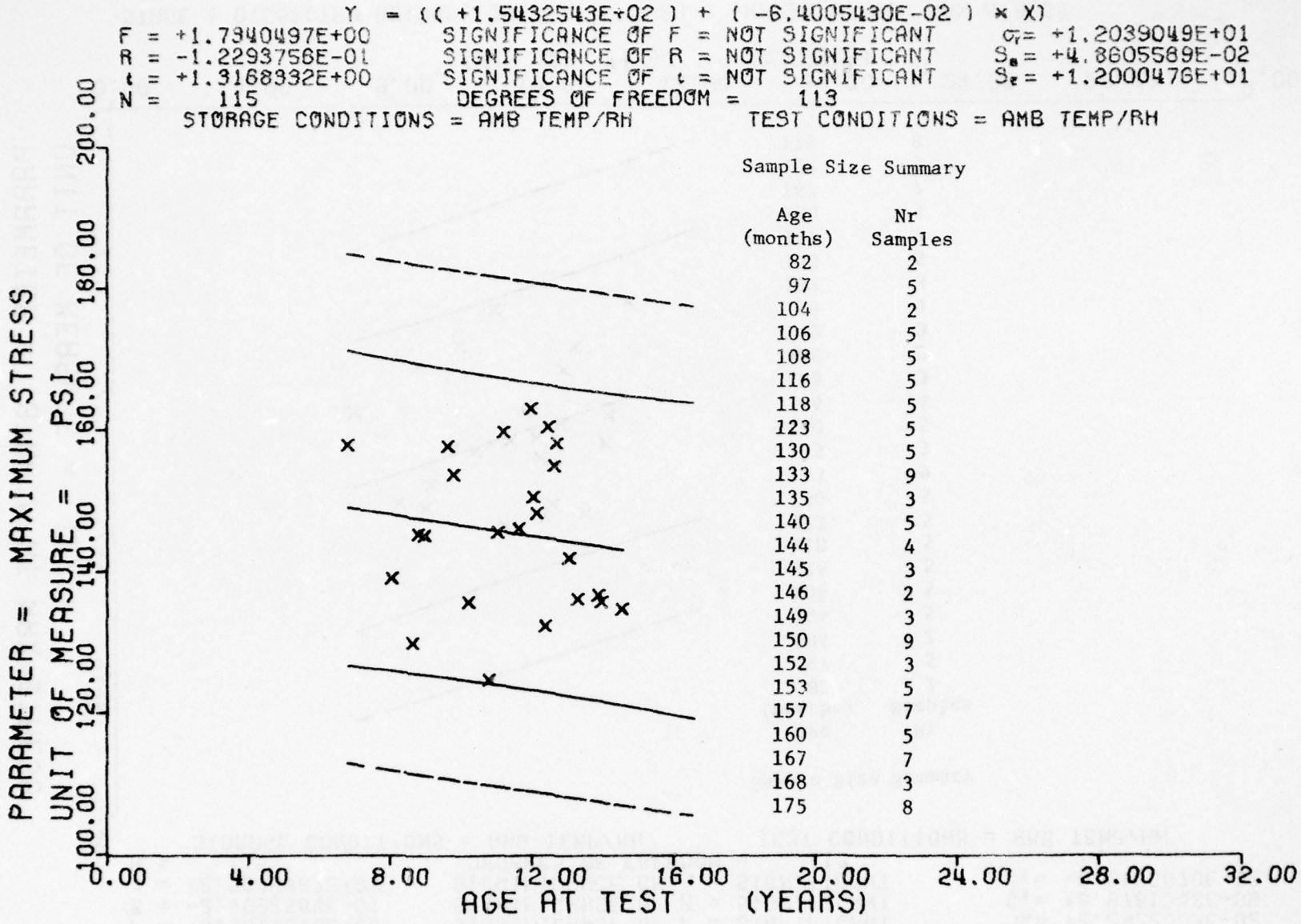
Figure 5



Sample Size Summary

Age (months)	Nr Samples
82	2
97	5
104	2
106	5
108	5
116	5
118	5
123	5
130	5
133	9
135	3
140	5
144	4
145	3
146	2
149	3
150	9
152	3
153	5
157	7
160	5
167	7
168	3
175	8

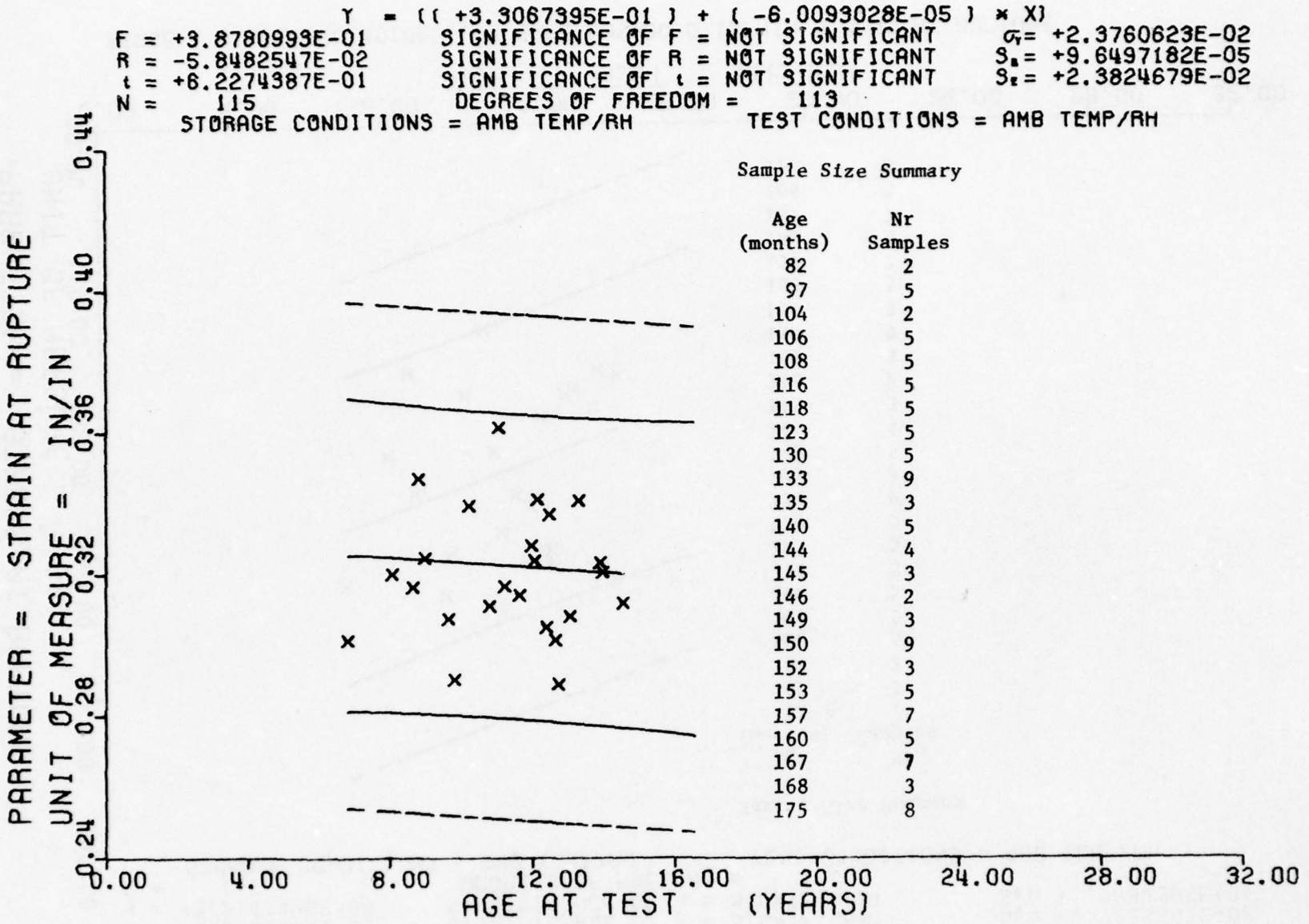
Figure 6



Sample Size Summary

Age (months)	Nr Samples
82	2
97	5
104	2
106	5
108	5
116	5
118	5
123	5
130	5
133	9
135	3
140	5
144	4
145	3
146	2
149	3
150	9
152	3
153	5
157	7
160	5
167	7
168	3
175	8

Figure 7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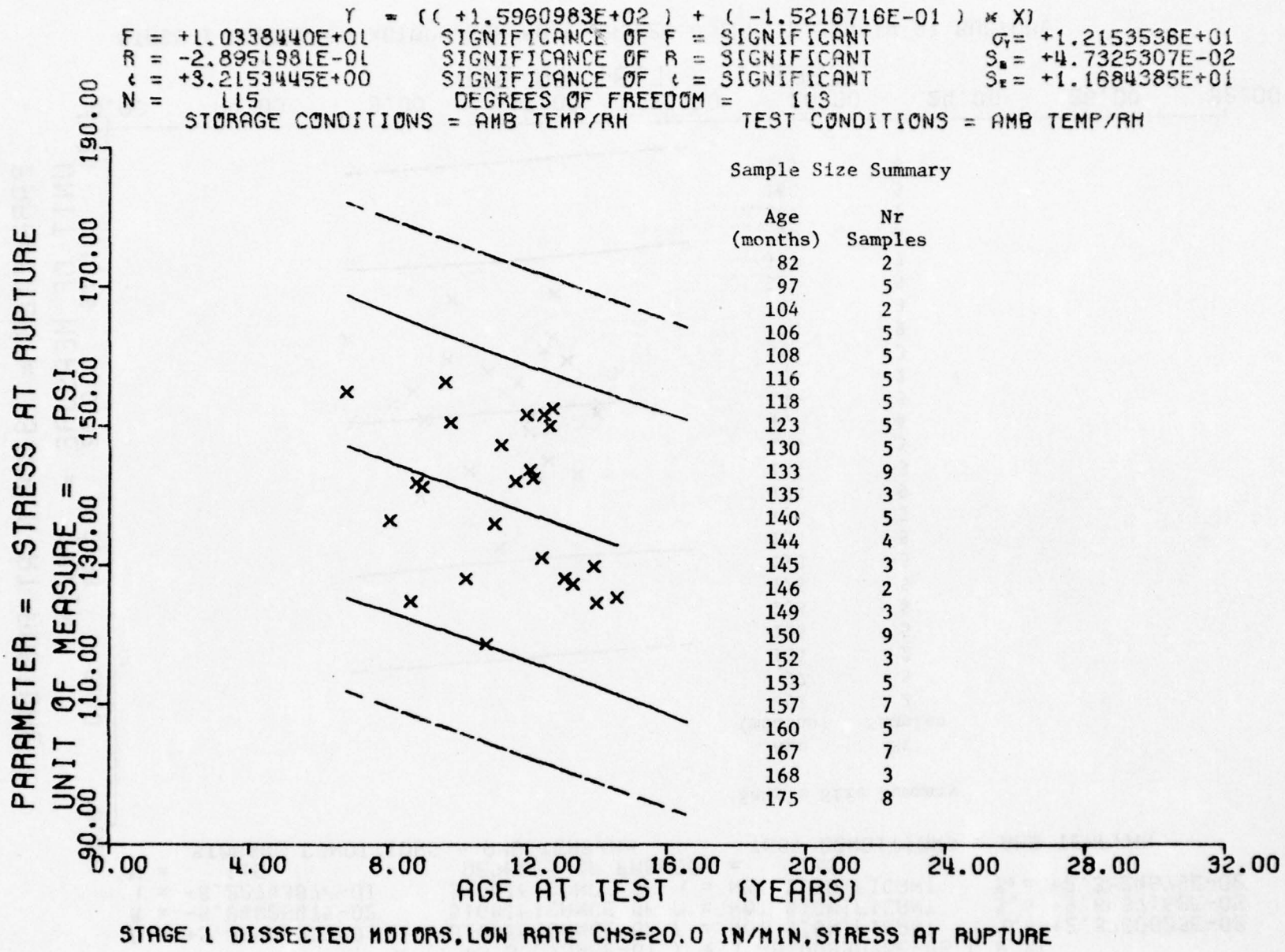
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples
82 2
97 5
104 2
106 5
108 5
116 5
118 5
123 5
130 5
133 9
135 3
140 5
144 4
145 3
146 2
149 3
150 9
152 3
153 5
157 7
160 5
167 7
168 3
175 8
PARAMETER = STRAIN AT RUPTURE
UNIT OF MEASURE = IN/IN
0.24
0.28
0.32
0.36
0.40
0.44
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
STAGE 1 DISSECTED MOTORS,LOW RATE CHS=20.0 IN/MIN,STRAIN AT RUPTURE

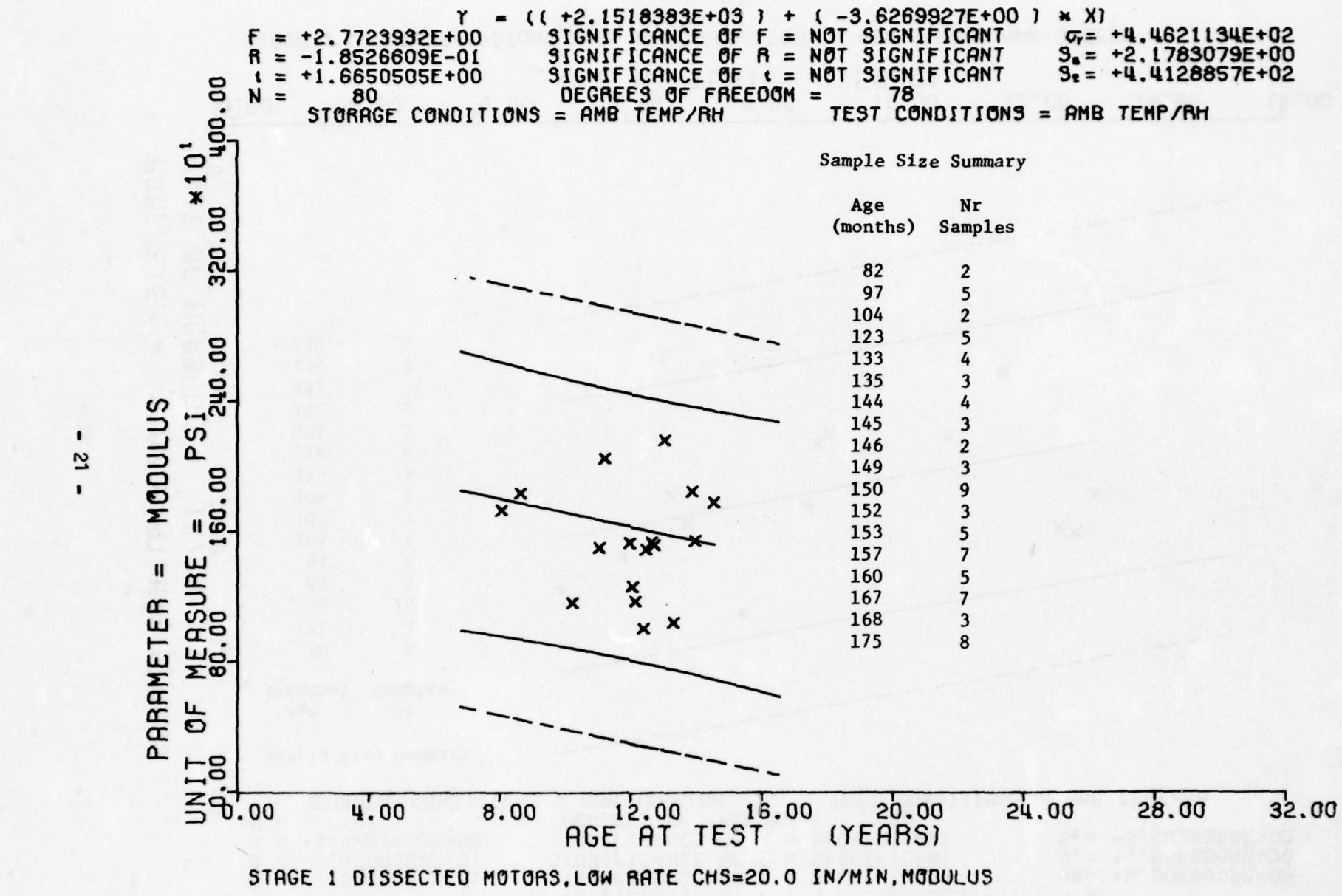
Figure 8



Sample Size Summary

Age (months)	Nr Samples
82	2
97	5
104	2
106	5
108	5
116	5
118	5
123	5
130	5
133	9
135	3
140	5
144	4
145	3
146	2
149	3
150	9
152	3
153	5
157	7
160	5
167	7
168	3
175	8

Figure 9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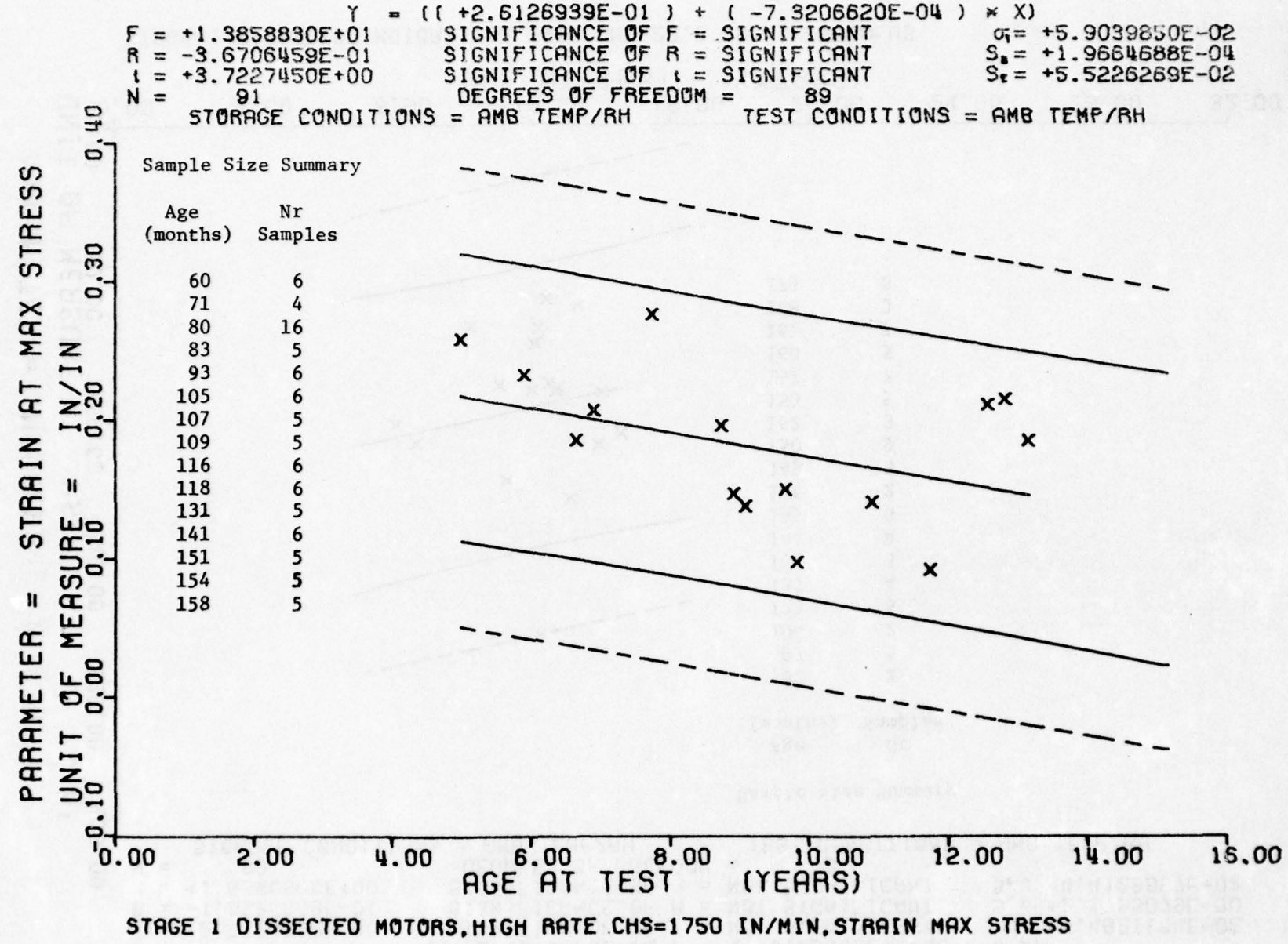
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples
82 2
97 5
104 2
123 5
133 4
135 3
144 4
145 3
146 2
149 3
150 9
152 3
153 5
157 7
160 5
167 7
168 3
175 8
PARAMETER = MODULUS
UNIT OF MEASURE = PSI *10¹
0.00
80.00
160.00
240.00
320.00
400.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
STAGE 1 DISSECTED MOTORS,LOW RATE CHS=20.0 IN/MIN,MODULUS

Figure 10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R = -3.6706459E-01 SIGNIFICANCE OF R = SIGNIFICANT
t = +3.7227450E+00 SIGNIFICANCE OF t = SIGNIFICANT
N = 91 DEGREES OF FREEDOM = 89
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples
60 6
71 4
80 16
83 5
93 6
105 6
107 5
109 5
116 6
118 6
131 5
141 6
151 5
154 5
158 5
PARAMETER = STRAIN AT MAX STRESS
UNIT OF MEASURE = IN/IN
0.40
0.30
0.20
0.10
0.00
-0.10
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
AGE AT TEST (YEARS)
STAGE 1 DISSECTED MOTORS, HIGH RATE CHS=1750 IN/MIN, STRAIN MAX STRESS

Figure 11

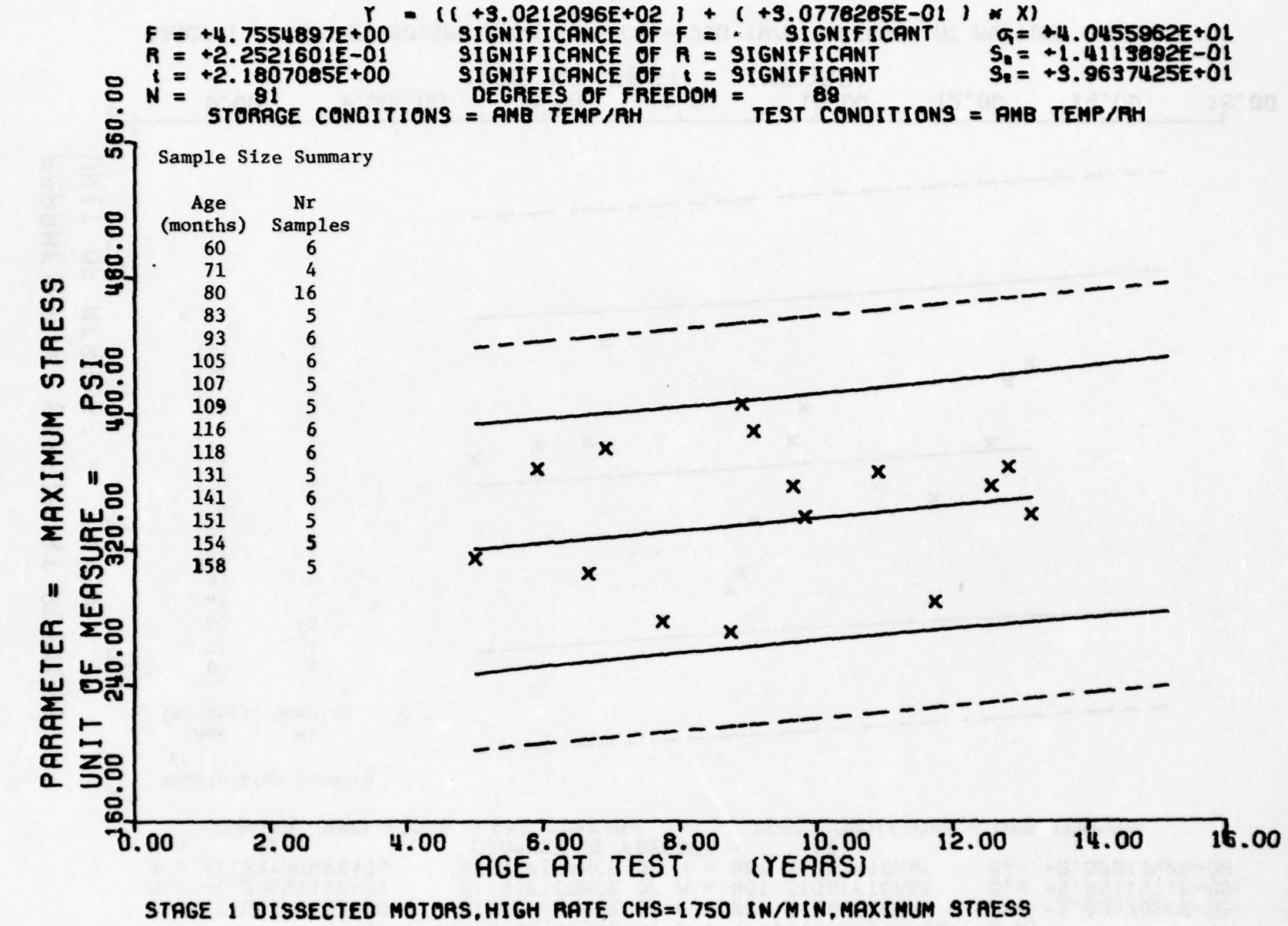

Y = ((+3.0212096E+02) + (+3.0778285E-01) * X)
F = +4.7554897E+00 SIGNIFICANCE OF F = SIGNIFICANT σ = +4.0455962E+01
R = +2.2521601E-01 SIGNIFICANCE OF R = SIGNIFICANT S_B = +1.4113892E-01
t = +2.1807085E+00 SIGNIFICANCE OF t = SIGNIFICANT S_E = +3.9637425E+01
N = 91 DEGREES OF FREEDOM = 89
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples
60 6
71 4
80 16
83 5
93 6
105 6
107 5
109 5
116 6
118 6
131 5
141 6
151 5
154 5
158 5
PARAMETER = MAXIMUM STRESS
UNIT OF MEASURE = PSI
160.00
240.00
320.00
400.00
480.00
560.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
AGE AT TEST (YEARS)
STAGE 1 DISSECTED MOTORS, HIGH RATE CHS=1750 IN/MIN, MAXIMUM STRESS

Figure 12

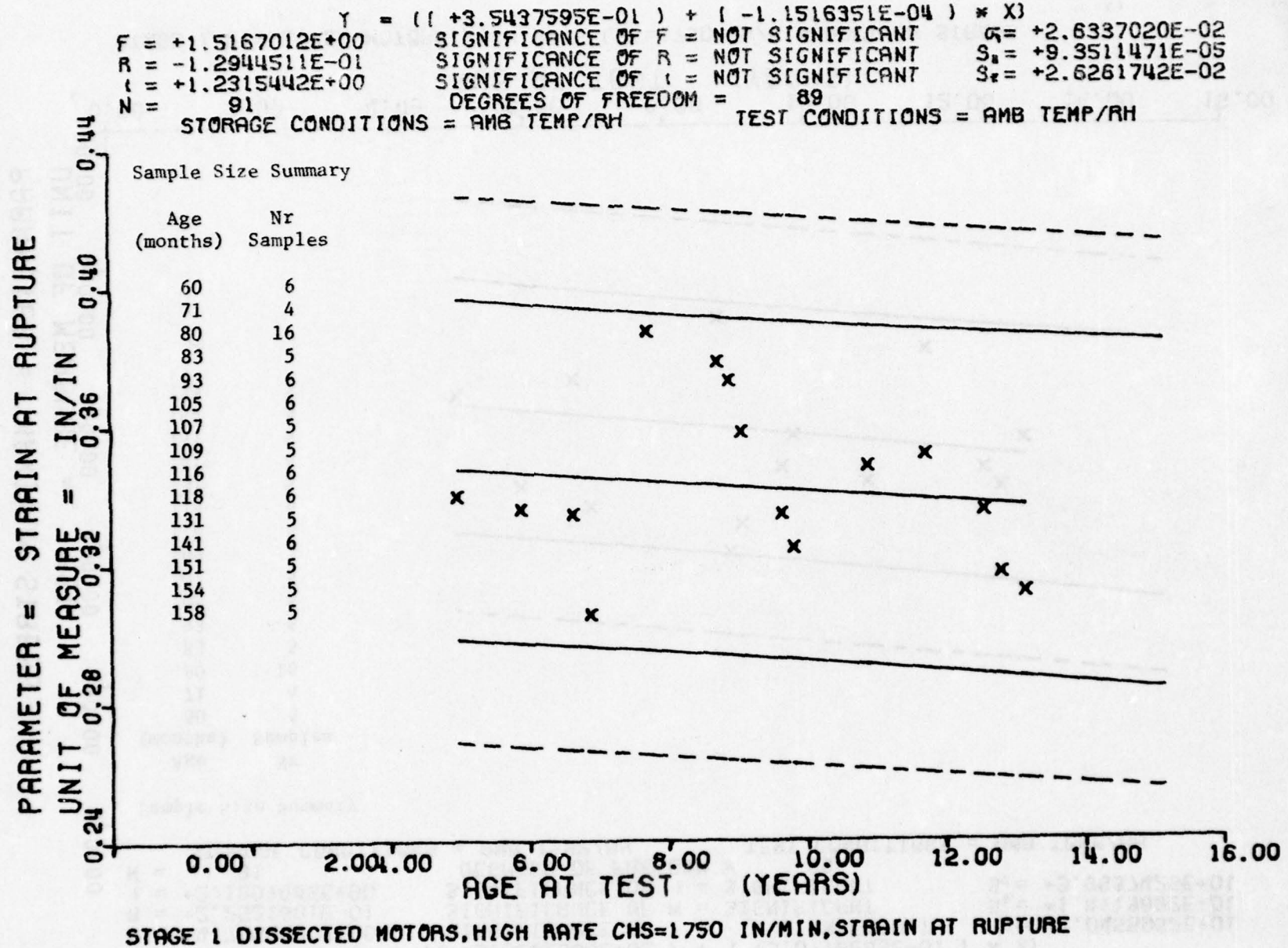

Y = (+3.5437595E-01) + (-1.1516351E-04) * X
F = +1.5167012E+00 SIGNIFICANCE OF F = NOT SIGNIFICANT σ = +2.6337020E-02
R = -1.2944511E-01 SIGNIFICANCE OF R = NOT SIGNIFICANT S_a = +9.3511471E-05
t = +1.2315442E+00 SIGNIFICANCE OF t = NOT SIGNIFICANT S_e = +2.6261742E-02
N = 91 DEGREES OF FREEDOM = 89
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples
60 6
71 4
80 16
83 5
93 6
105 6
107 5
109 5
116 6
118 6
131 5
141 6
151 5
154 5
158 5
PARAMETER = STRAIN AT RUPTURE
UNIT OF MEASURE = IN/IN
0.44
0.40
0.36
0.32
0.28
0.24
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
AGE AT TEST (YEARS)
STAGE 1 DISSECTED MOTORS, HIGH RATE CHS=1750 IN/MIN, STRAIN AT RUPTURE

Figure 13

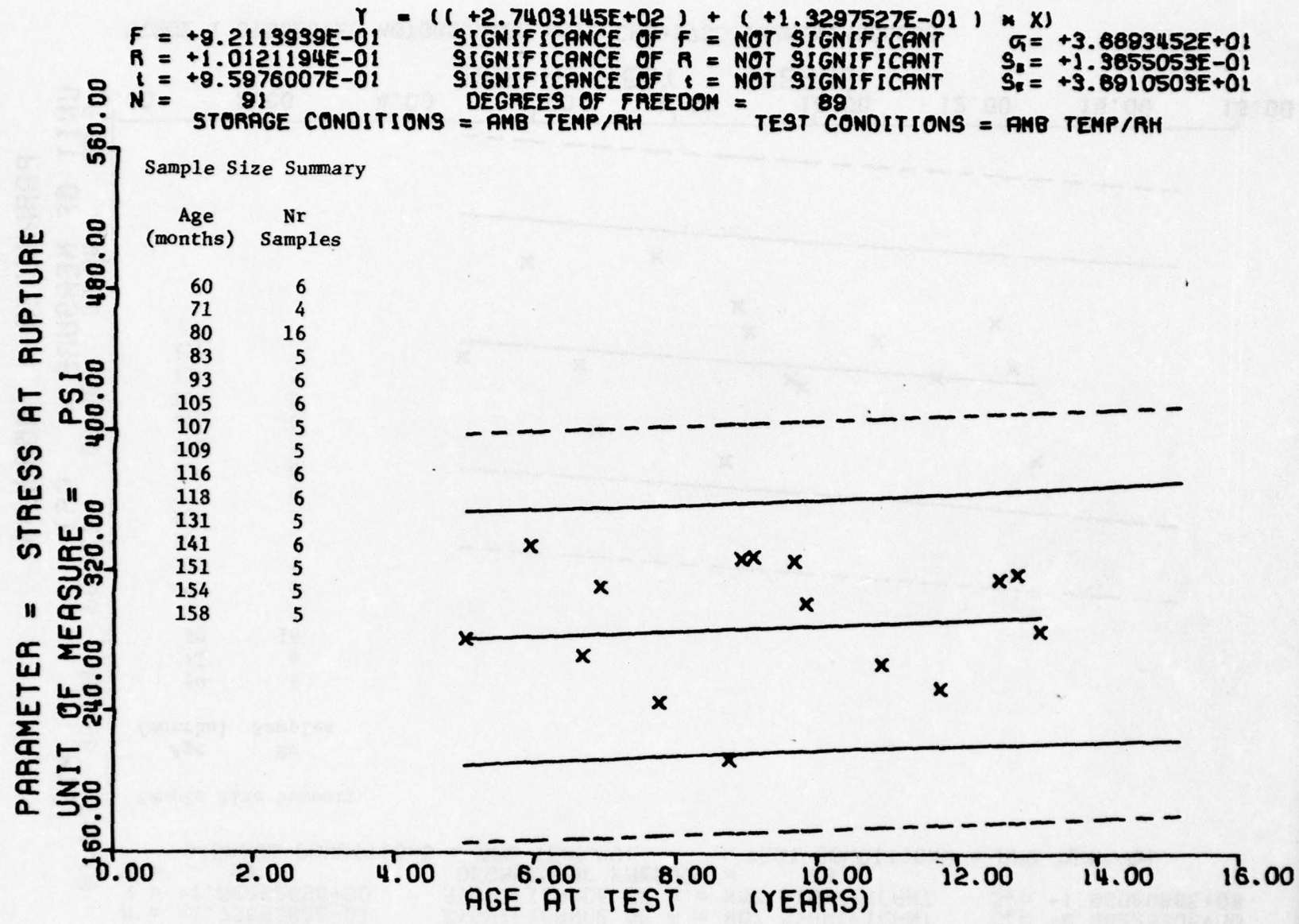

Y = ((+2.7403145E+02) + (+1.3297527E-01) * X)
F = +9.2113939E-01 SIGNIFICANCE OF F = NOT SIGNIFICANT σ = +3.8893452E+01
R = +1.0121194E-01 SIGNIFICANCE OF R = NOT SIGNIFICANT S = +1.3855053E-01
t = +9.5976007E-01 SIGNIFICANCE OF t = NOT SIGNIFICANT S = +3.8910503E+01
N = 91 DEGREES OF FREEDOM = 89
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples
60 6
71 4
80 16
83 5
93 6
105 6
107 5
109 5
116 6
118 6
131 5
141 6
151 5
154 5
158 5
PARAMETER = STRESS AT RUPTURE
UNIT OF MEASURE = PSI
160.00
240.00
320.00
400.00
480.00
560.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
AGE AT TEST (YEARS)
STAGE 1 DISSECTED MOTORS, HIGH RATE CHS=1750 IN/MIN, STRESS AT RUPTURE

Figure 14

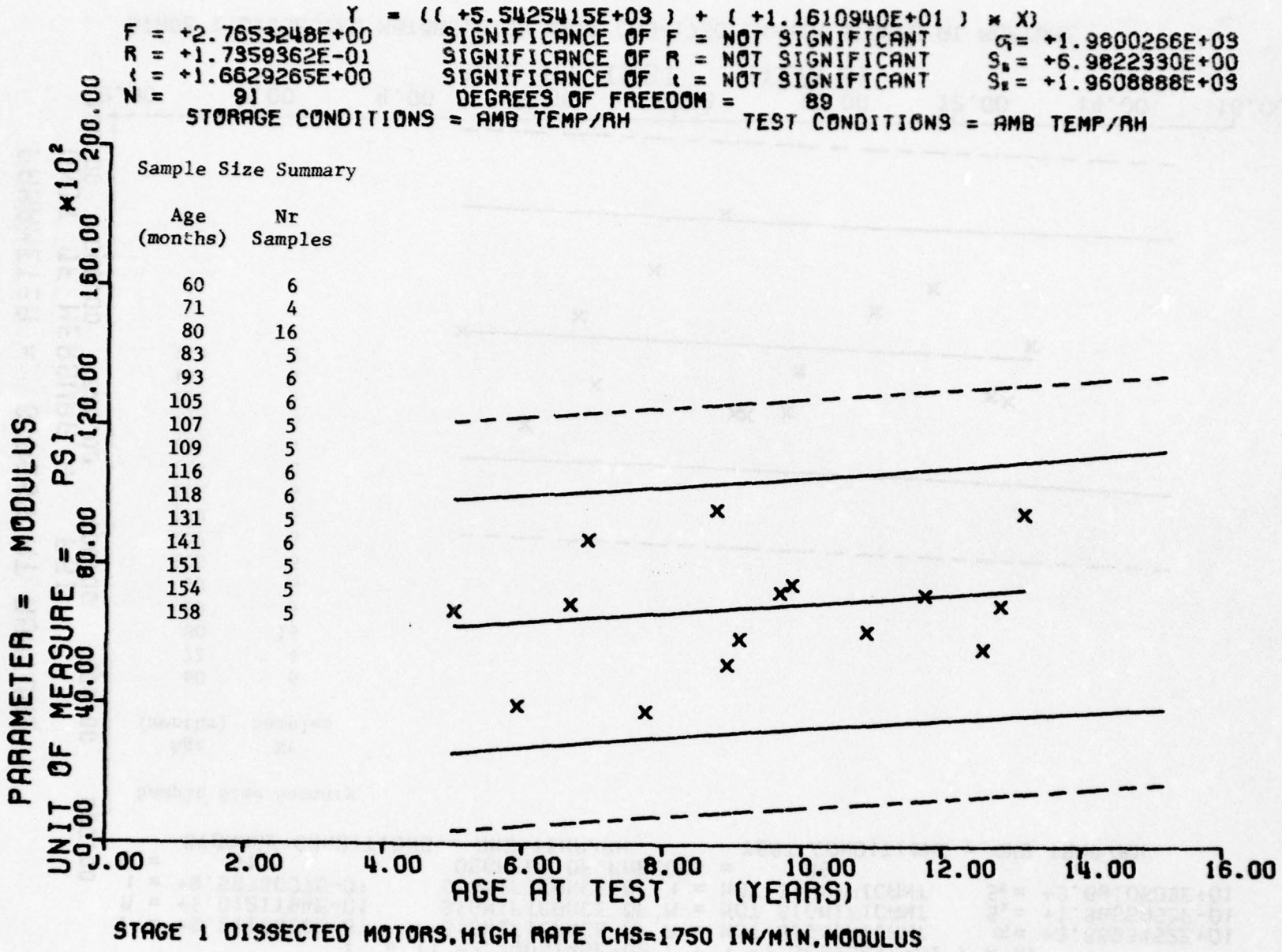

Y = ((+5.5425415E+03) + (+1.1610940E+01) * X)
F = +2.7653248E+00 SIGNIFICANCE OF F = NOT SIGNIFICANT σ1 = +1.9800266E+03
R = +1.7359362E-01 SIGNIFICANCE OF R = NOT SIGNIFICANT S1 = +6.9822330E+00
t = +1.6629265E+00 SIGNIFICANCE OF t = NOT SIGNIFICANT S2 = +1.9608888E+03
N = 91 DEGREES OF FREEDOM = 89
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples
60 6
71 4
80 16
83 5
93 6
105 6
107 5
109 5
116 6
118 6
131 5
141 6
151 5
154 5
158 5
PARAMETER = MODULUS
UNIT OF MEASURE = PSI *10²
0.00
40.00
80.00
120.00
160.00
200.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
AGE AT TEST (YEARS)
STAGE 1 DISSECTED MOTORS, HIGH RATE CHS=1750 IN/MIN, MODULUS

Figure 15

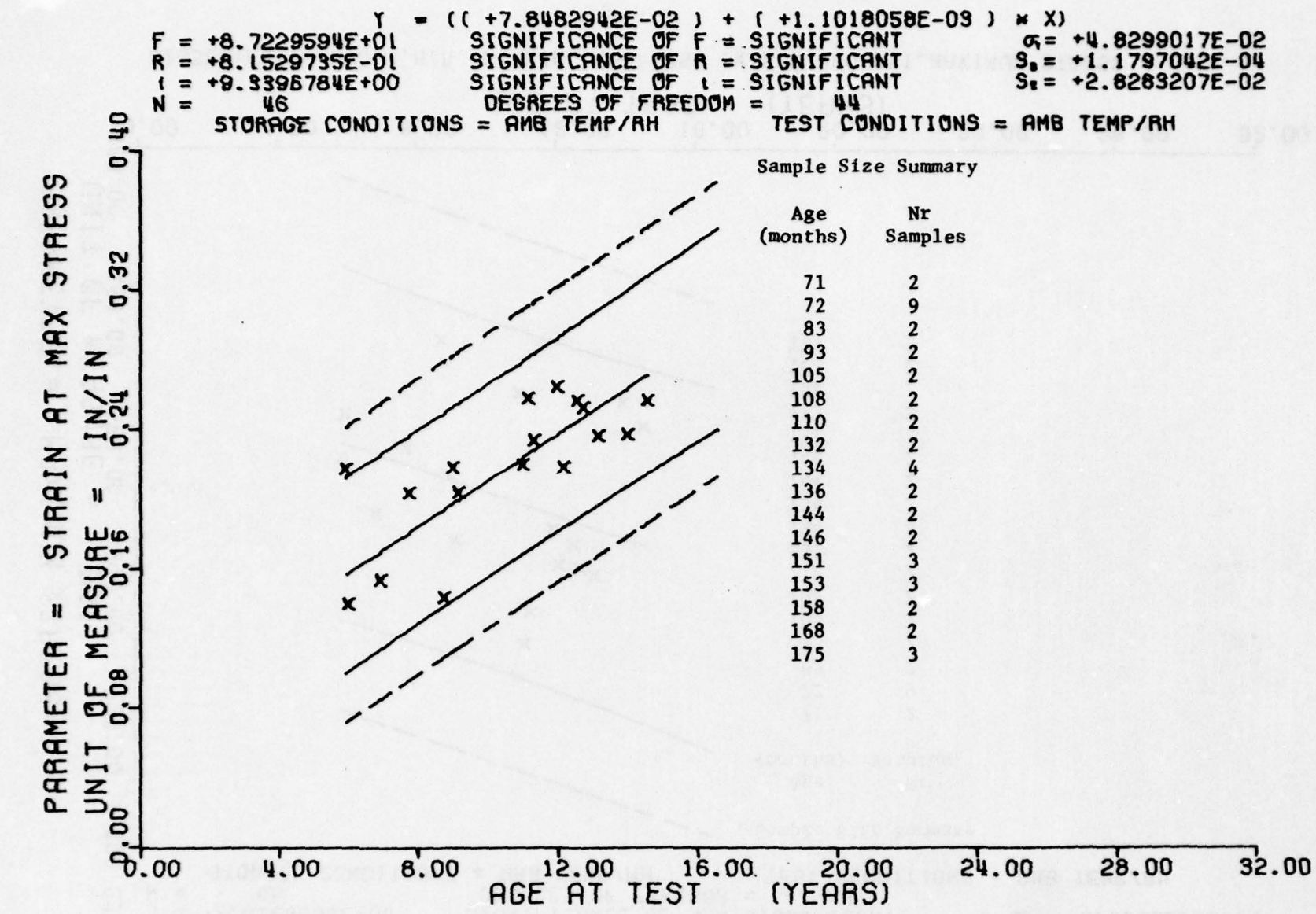

Y = ((+7.8482942E-02) + (+1.1018058E-03) * X)
F = +8.7229594E+01 SIGNIFICANCE OF F = SIGNIFICANT σ = +4.8299017E-02
R = +8.1529735E-01 SIGNIFICANCE OF R = SIGNIFICANT S_b = +1.1797042E-04
t = +9.3396784E+00 SIGNIFICANCE OF t = SIGNIFICANT S_E = +2.8283207E-02
N = 46 DEGREES OF FREEDOM = 44
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
PARAMETER = STRAIN AT MAX STRESS
UNIT OF MEASURE = IN/IN
0.00
0.08
0.16
0.24
0.32
0.40
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
Sample Size Summary
Age (months) Nr Samples
71 2
72 9
83 2
93 2
105 2
108 2
110 2
132 2
134 4
136 2
144 2
146 2
151 3
153 3
158 2
168 2
175 3
DISSECTED TP-H1011,H.R.TRIAXIAL CHS=1750 IN/MIN,600 PSI,STRAIN MAX STRESS

Figure 16

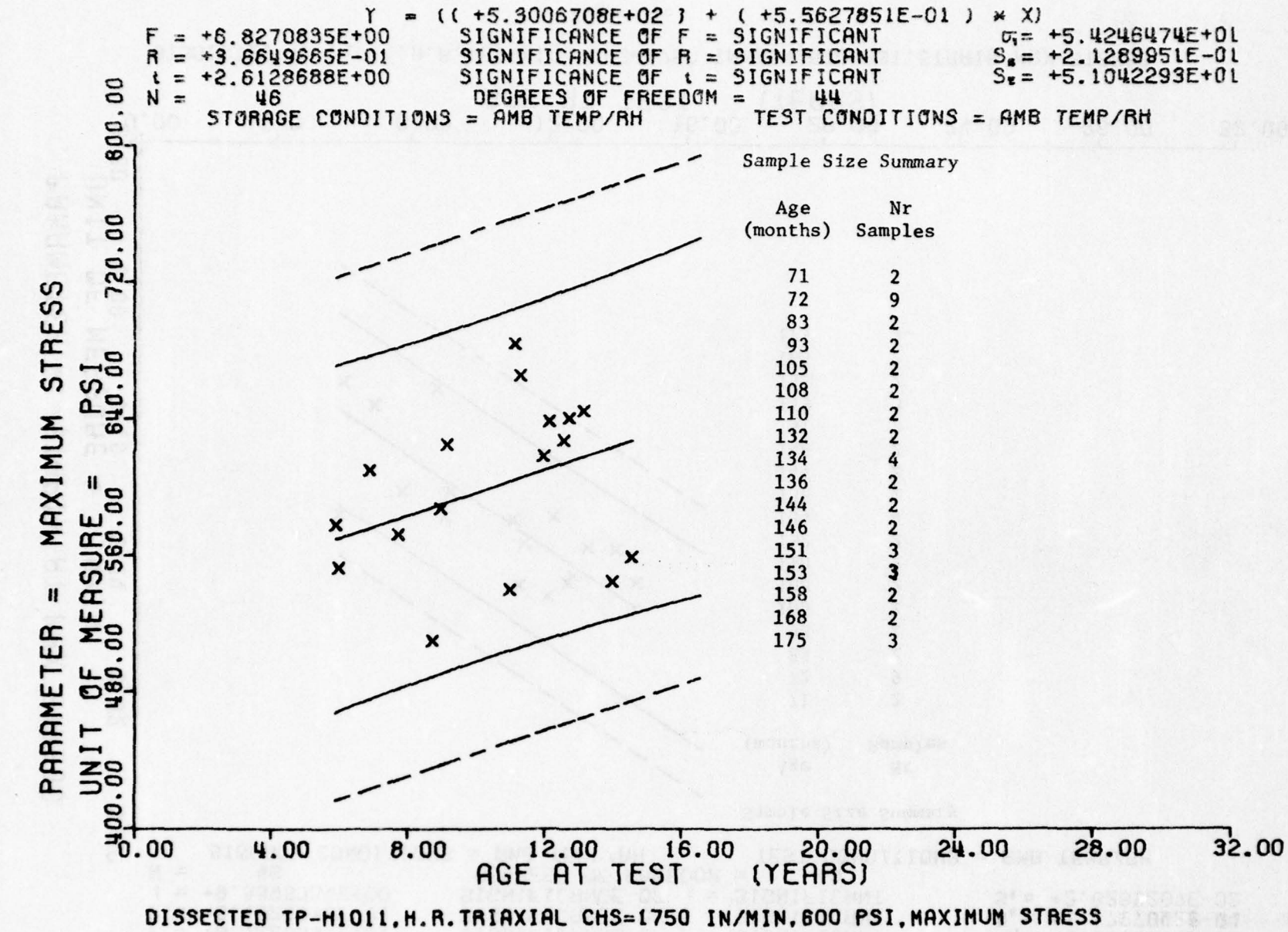

Y = ((+5.3006708E+02) + (+5.5627851E-01) * X)
F = +6.8270835E+00 SIGNIFICANCE OF F = SIGNIFICANT σ1 = +5.4246474E+01
R = +3.6649665E-01 SIGNIFICANCE OF R = SIGNIFICANT Sa = +2.1289851E-01
t = +2.6128688E+00 SIGNIFICANCE OF t = SIGNIFICANT Se = +5.1042293E+01
N = 46 DEGREES OF FREEDOM = 44
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples
71 2
72 9
83 2
93 2
105 2
108 2
110 2
132 2
134 4
136 2
144 2
146 2
151 3
153 3
158 2
168 2
175 3
PARAMETER = MAXIMUM STRESS
UNIT OF MEASURE = PSI
400.00
480.00
560.00
640.00
720.00
800.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
DISSECTED TP-H1011,H.R.TRIAXIAL CHS=1750 IN/MIN,600 PSI,MAXIMUM STRESS

Figure 17

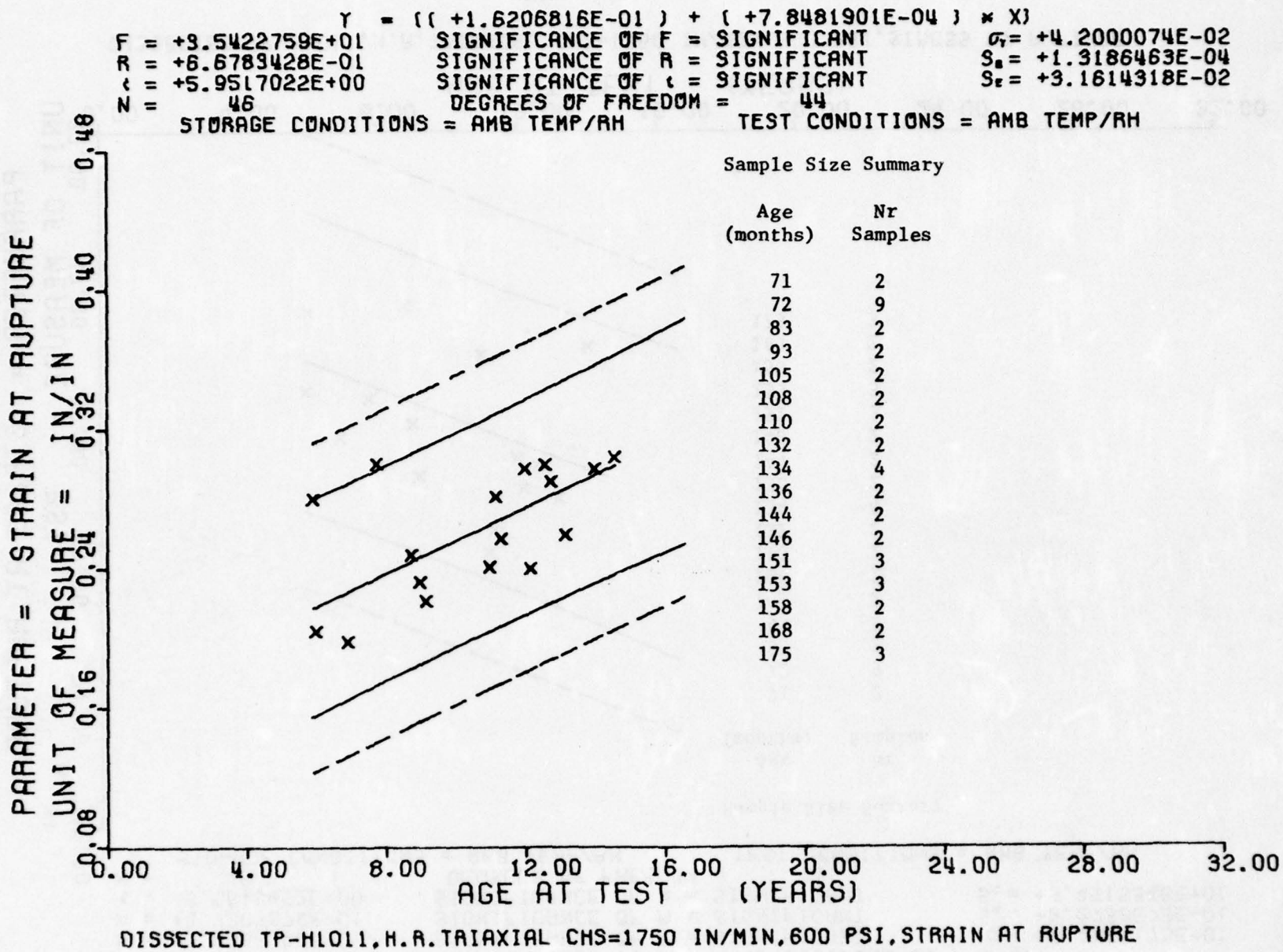

Y = ((+1.6206816E-01) + (+7.8481901E-04) * X)
F = +3.5422759E+01 SIGNIFICANCE OF F = SIGNIFICANT σr= +4.2000074E-02
R = +6.6783428E-01 SIGNIFICANCE OF R = SIGNIFICANT Sa= +1.3186463E-04
t = +5.9517022E+00 SIGNIFICANCE OF t = SIGNIFICANT Se= +3.1614318E-02
N = 46 DEGREES OF FREEDOM = 44
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples
71 2
72 9
83 2
93 2
105 2
108 2
110 2
132 2
134 4
136 2
144 2
146 2
151 3
153 3
158 2
168 2
175 3
PARAMETER = STRAIN AT RUPTURE
UNIT OF MEASURE = IN/IN
0,08
0,16
0,24
0,32
0,40
0,48
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
DISSECTED TP-HL011,H.R.TRIAXIAL CHS=1750 IN/MIN,600 PSI,STRAIN AT RUPTURE

Figure 18

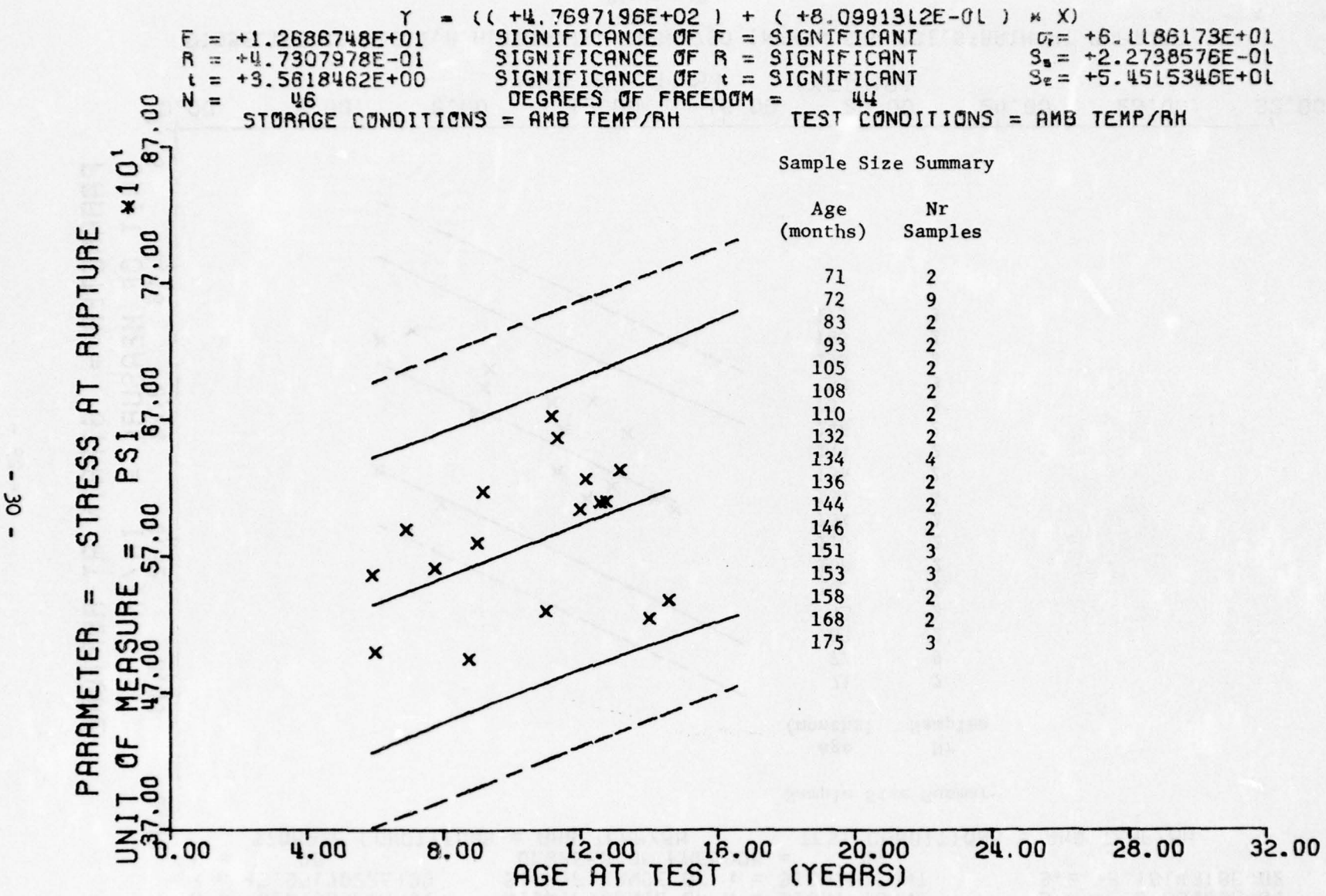

Y = ((+4.7697196E+02) + (+8.0991312E-01) * X)
F = +1.2686748E+01 SIGNIFICANCE OF F = SIGNIFICANT σr = +6.1186173E+01
R = +4.7307978E-01 SIGNIFICANCE OF R = SIGNIFICANT Sa = +2.2738576E-01
t = +3.5618462E+00 SIGNIFICANCE OF t = SIGNIFICANT Se = +5.4515346E+01
N = 46 DEGREES OF FREEDOM = 44
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples
71 2
72 9
83 2
93 2
105 2
108 2
110 2
132 2
134 4
136 2
144 2
146 2
151 3
153 3
158 2
168 2
175 3
PARAMETER = STRESS AT RUPTURE
UNIT OF MEASURE = PSI *10¹
87.00
77.00
67.00
57.00
47.00
37.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
DISSECTED TP-H1011,H.R.TRIAXIAL CHS=1750 IN/MIN,600 PSI,STRESS AT RUPTURE

Figure 19

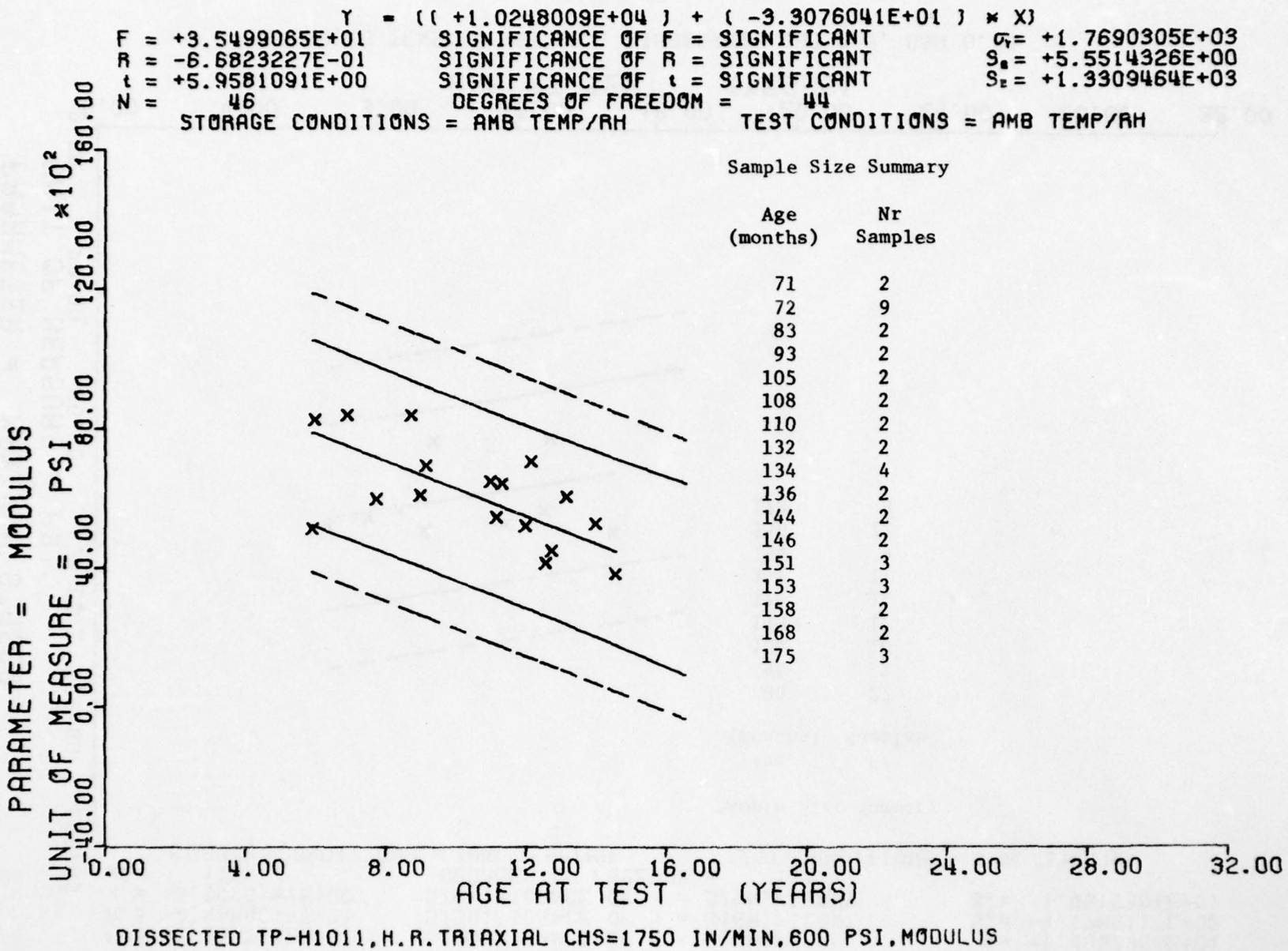
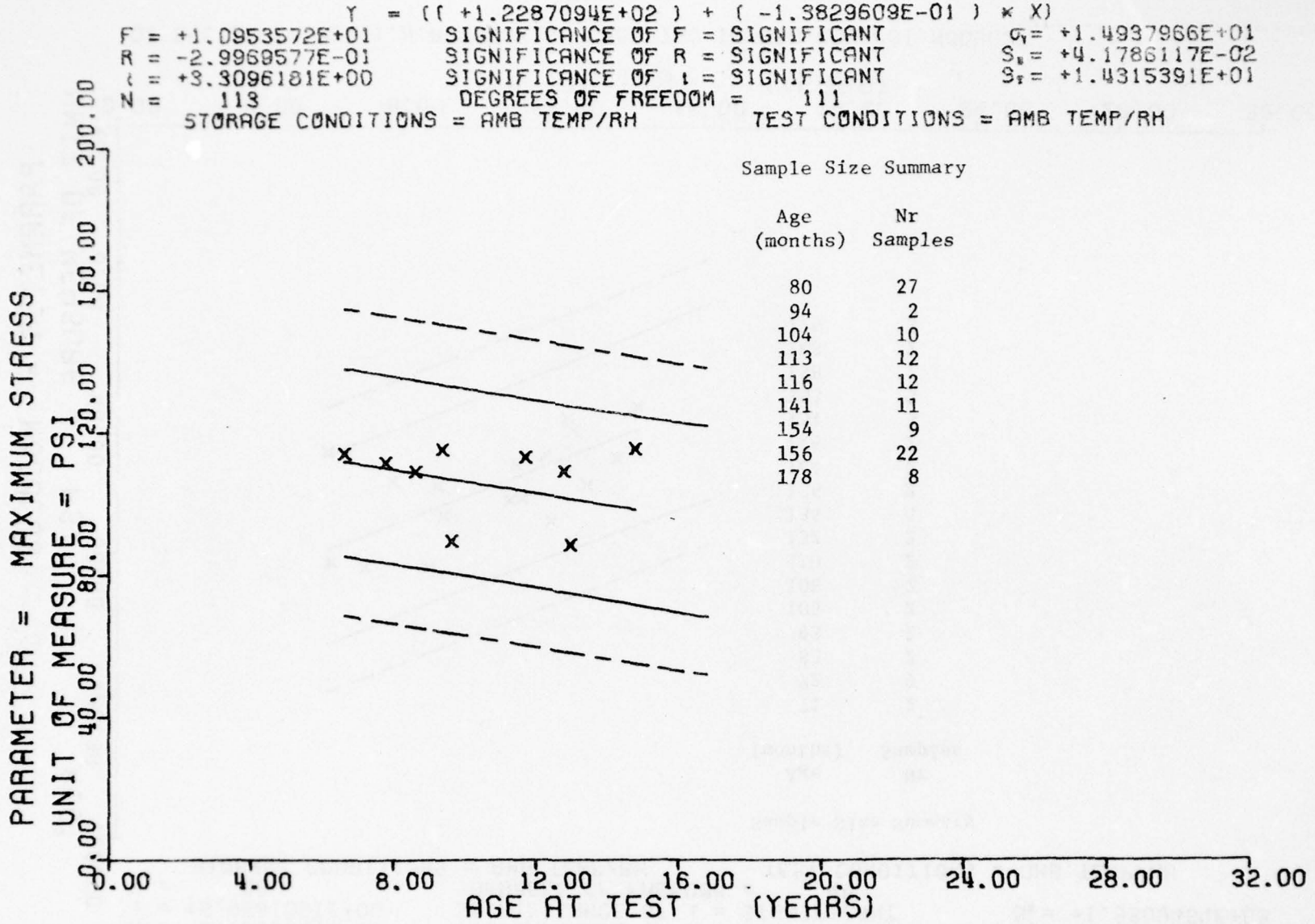
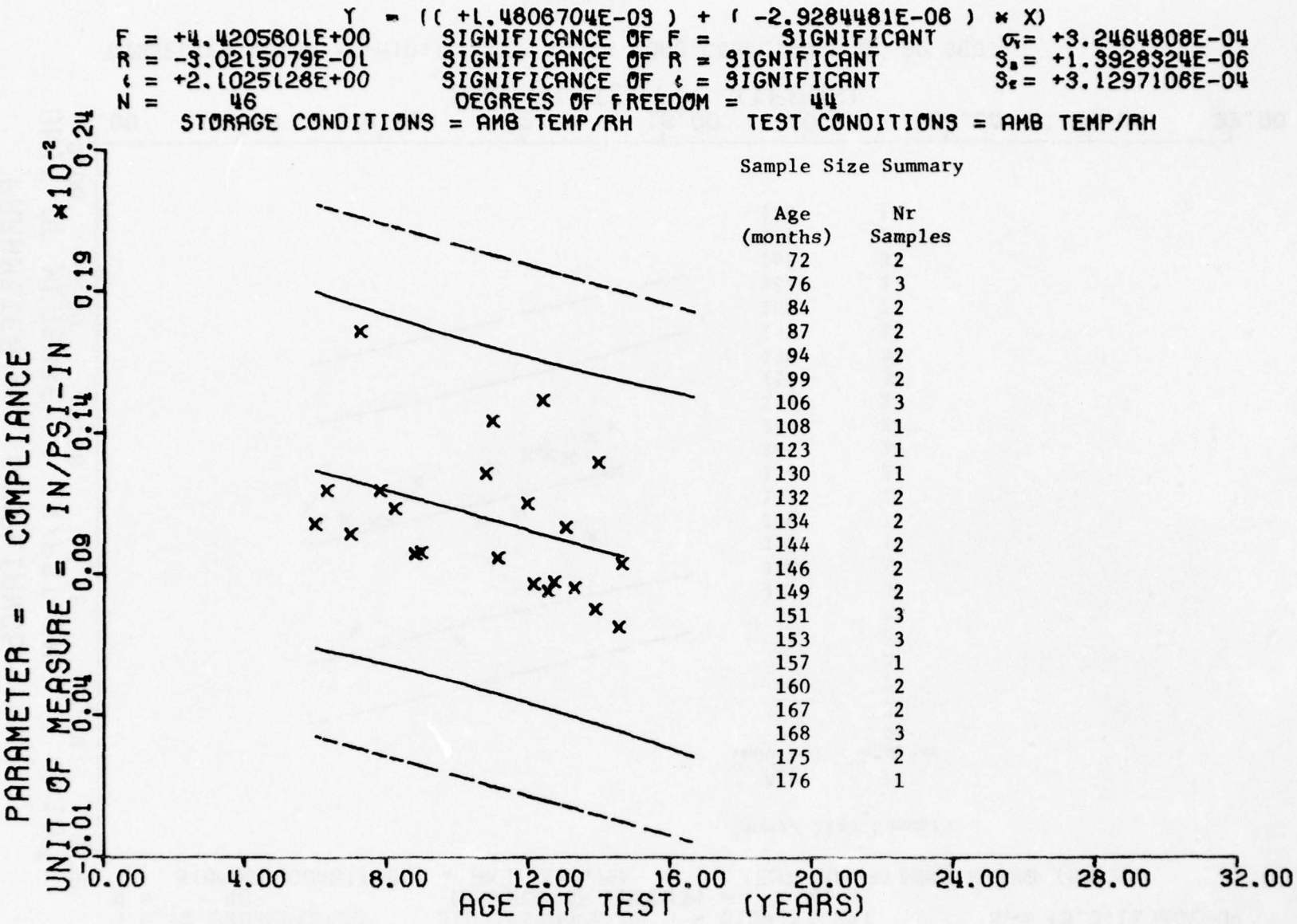

Y = ((+1.0248009E+04) + (-3.3076041E+01) * X)
F = +3.5499065E+01 SIGNIFICANCE OF F = SIGNIFICANT
R = -6.6823227E-01 SIGNIFICANCE OF R = SIGNIFICANT
t = +5.9581091E+00 SIGNIFICANCE OF t = SIGNIFICANT
N = 46 DEGREES OF FREEDOM = 44
STORAGE CONDITIONS = AMB TEMP/RH
TEST CONDITIONS = AMB TEMP/RH
σT = +1.7690305E+03
Se = +5.5514326E+00
Sz = +1.3309464E+03
Sample Size Summary
Age (months) Nr Samples
71 2
72 9
83 2
93 2
105 2
108 2
110 2
132 2
134 4
136 2
144 2
146 2
151 3
153 3
158 2
168 2
175 3
PARAMETER = MODULUS
UNIT OF MEASURE = PSI *10²
160.00
120.00
80.00
40.00
0.00
-40.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
DISSECTED TP-H1011,H.R.TRIAXIAL CHS=1750 IN/MIN,600 PSI,MODULUS

Figure 20



CASEBOND TENSILE, STAGE 1 DISSECTED, CHS 0.2, CSA 0.75

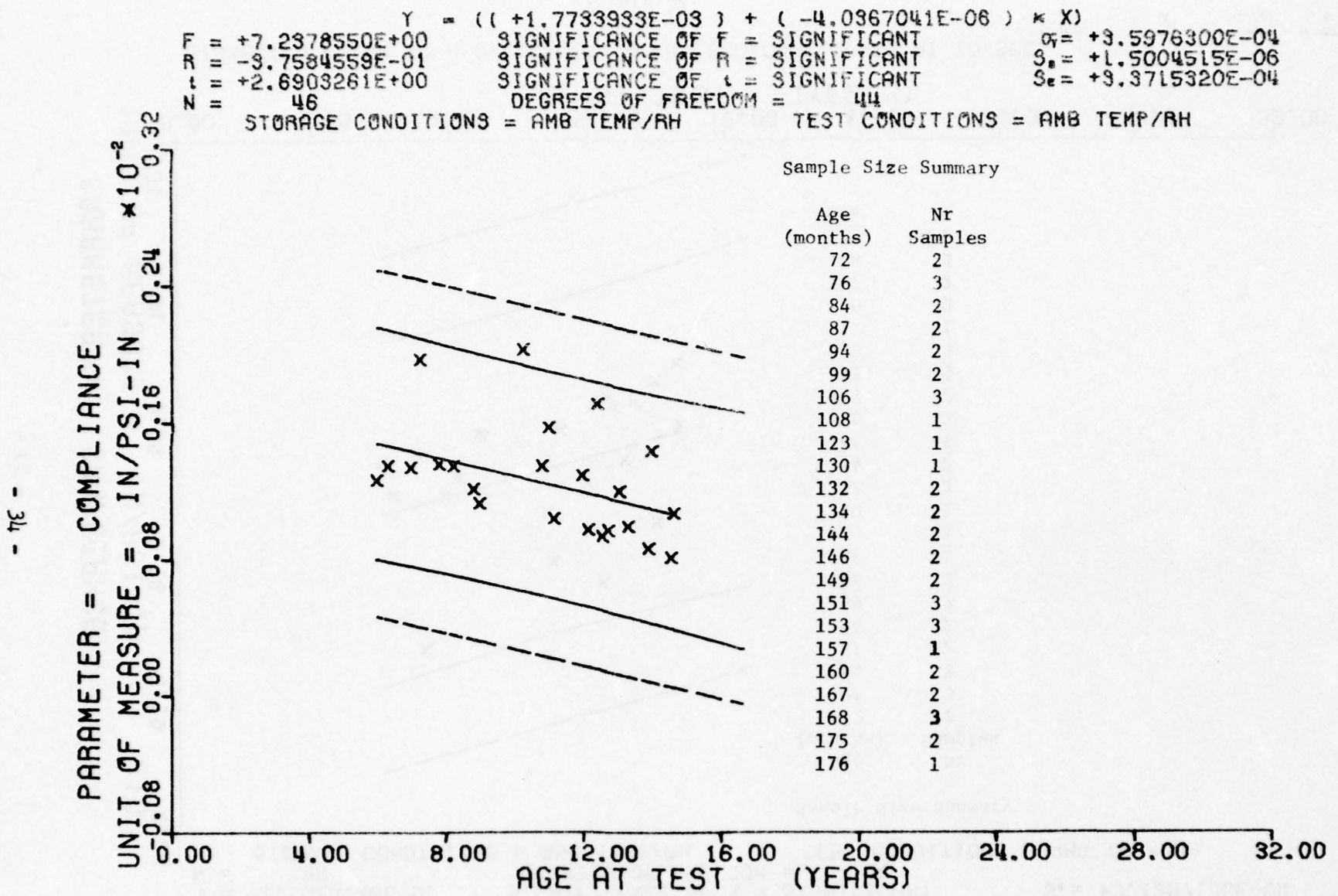
Figure 21



Sample Size Summary

Age (months)	Nr Samples
72	2
76	3
84	2
87	2
94	2
99	2
106	3
108	1
123	1
130	1
132	2
134	2
144	2
146	2
149	2
151	3
153	3
157	1
160	2
167	2
168	3
175	2
176	1

Figure 22



Sample Size Summary

Age (months)	Nr Samples
72	2
76	3
84	2
87	2
94	2
99	2
106	3
108	1
123	1
130	1
132	2
134	2
144	2
146	2
149	2
151	3
153	3
157	1
160	2
167	2
168	3
175	2
176	1

DISSECTED MOTOR TP-H1011, CREEP 10 LB LOAD, COMPLIANCE AT 20 SEC.

Figure 23

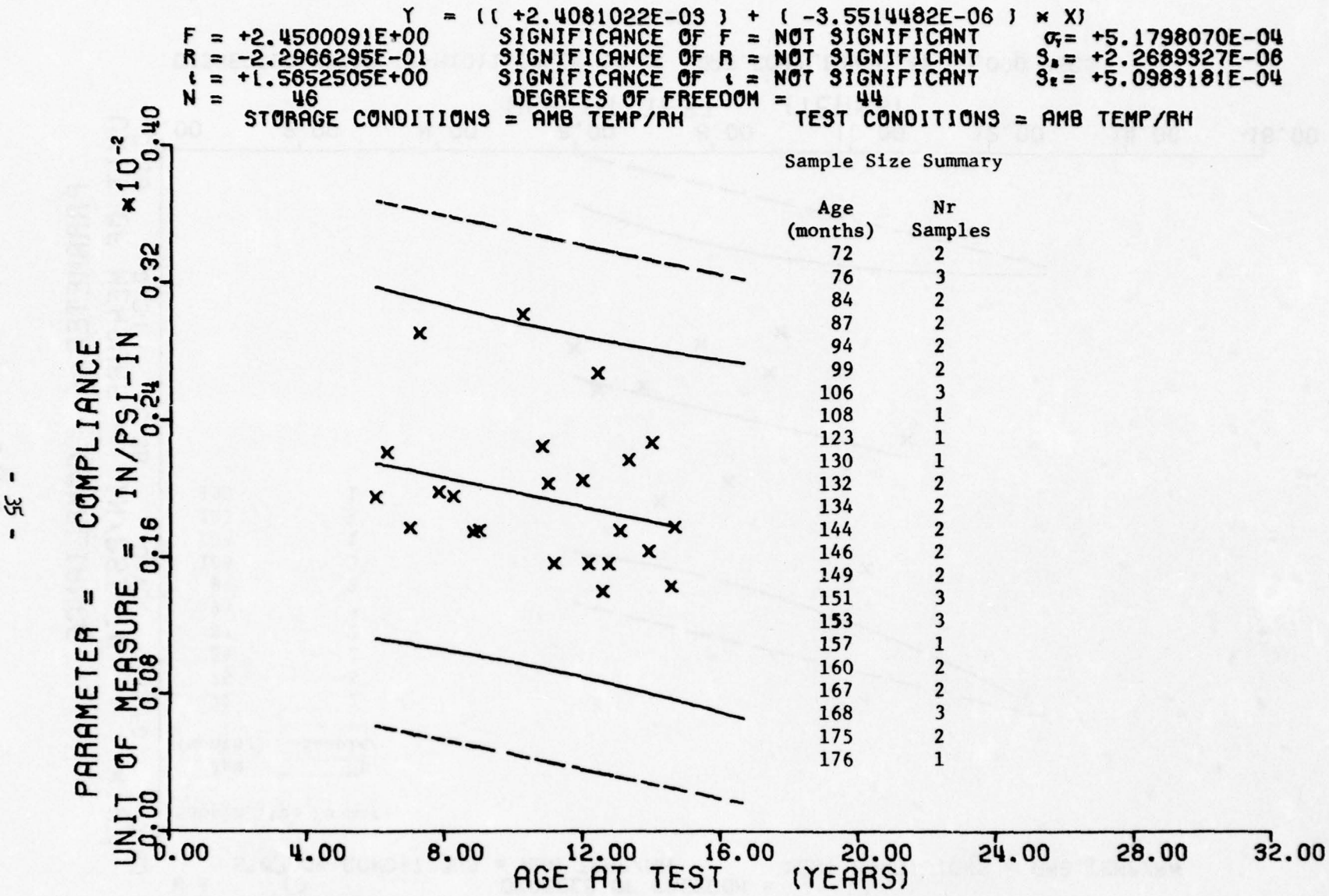
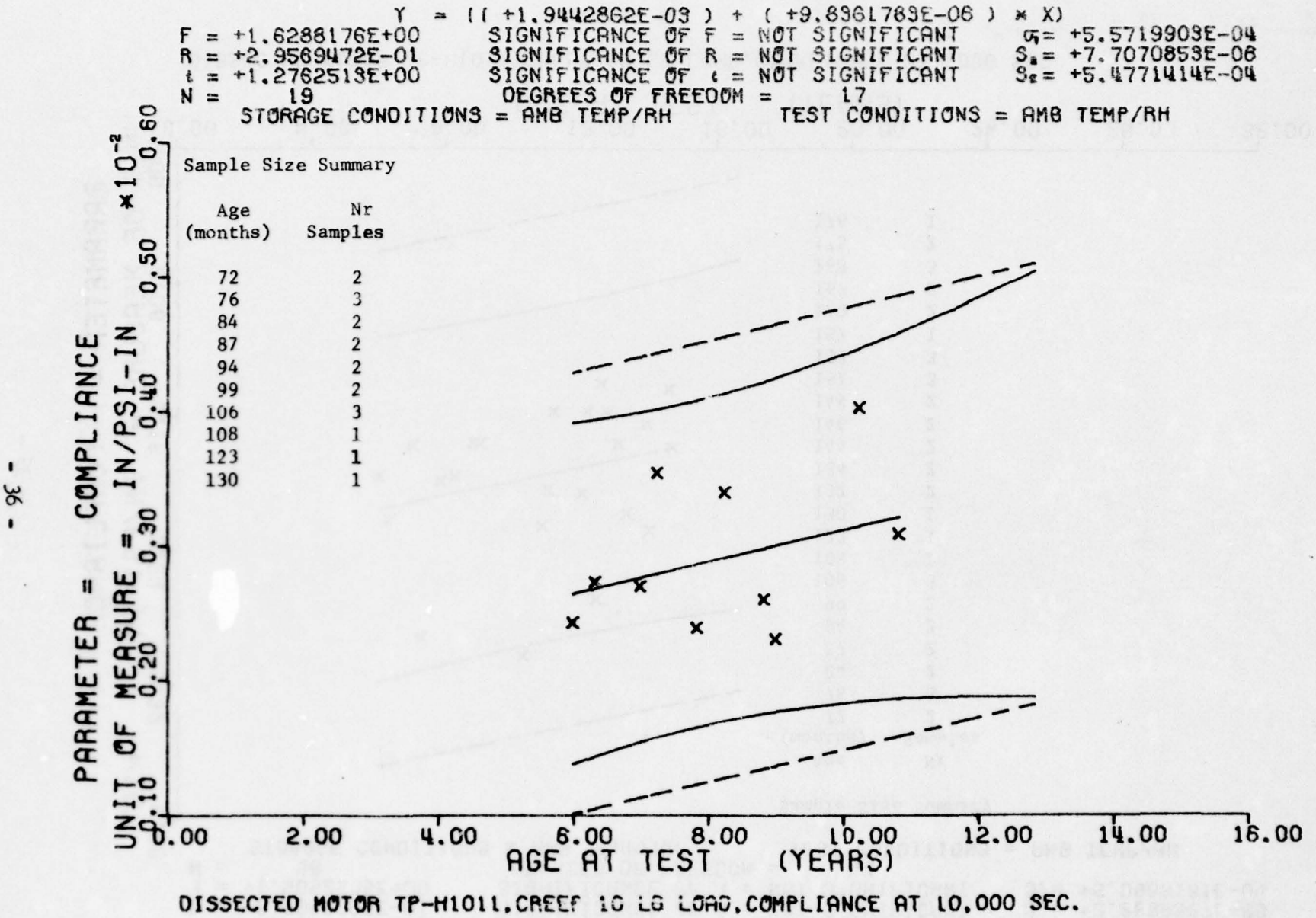
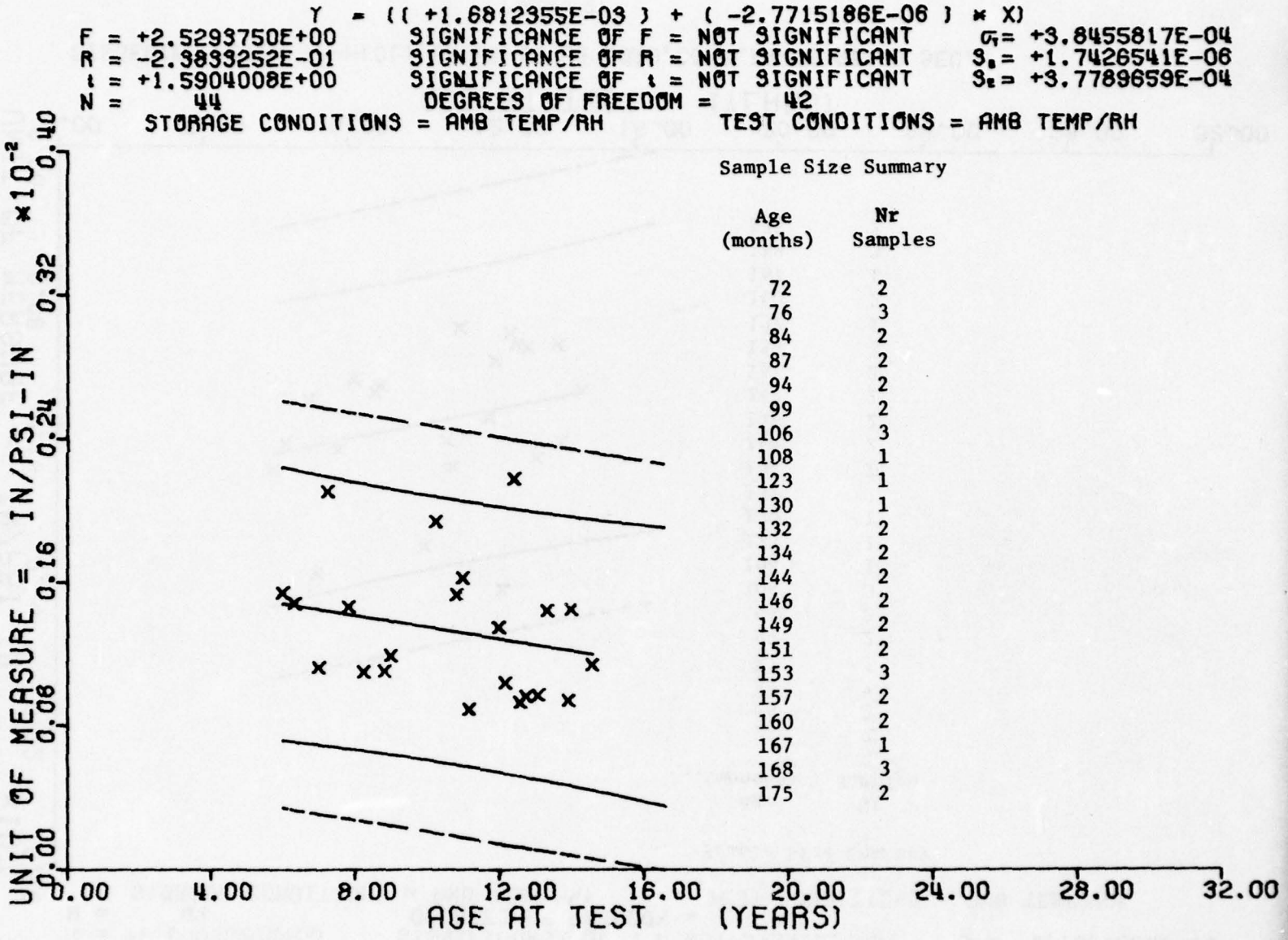

Y = ((+2.4081022E-03) + (-3.5514482E-06) * X)
F = +2.4500091E+00 SIGNIFICANCE OF F = NOT SIGNIFICANT σ = +5.1798070E-04
R = -2.2966295E-01 SIGNIFICANCE OF R = NOT SIGNIFICANT S = +2.2689327E-06
t = +1.5652505E+00 SIGNIFICANCE OF t = NOT SIGNIFICANT S = +5.0983181E-04
N = 46 DEGREES OF FREEDOM = 44
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples
72 2
76 3
84 2
87 2
94 2
99 2
106 3
108 1
123 1
130 1
132 2
134 2
144 2
146 2
149 2
151 3
153 3
157 1
160 2
167 2
168 3
175 2
176 1
PARAMETER = COMPLIANCE
UNIT OF MEASURE = IN/PSI-IN *10^-2
0.00
0.08
0.16
0.24
0.32
0.40
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
DISSECTED MOTOR TP-H1011, CREEP 10 LB LOAD, COMPLIANCE AT 1000 SEC.

Figure 24



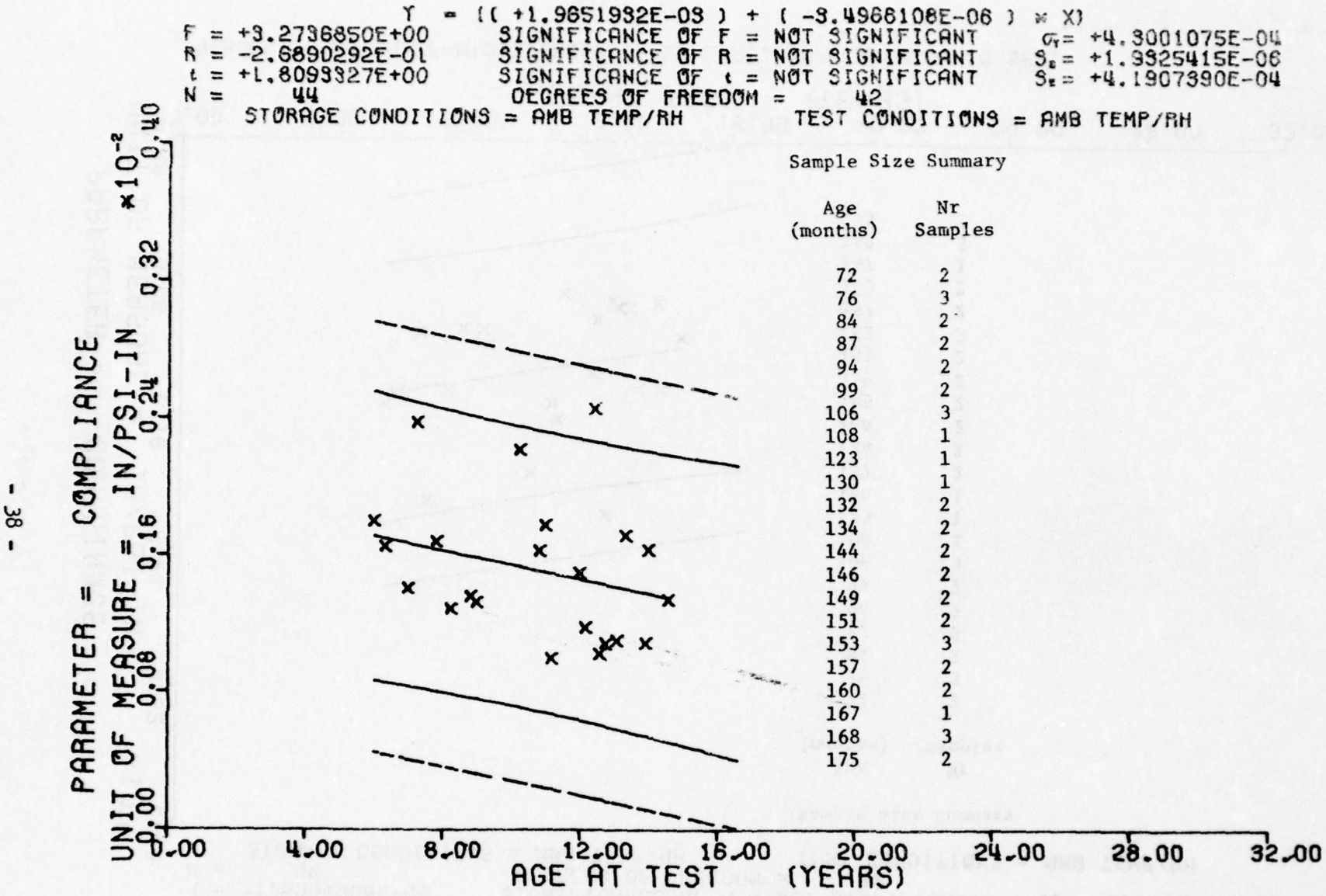
DISSECTED MOTOR TP-H1011, CREEP 10 LB LOAD, COMPLIANCE AT 10,000 SEC.

Figure 25



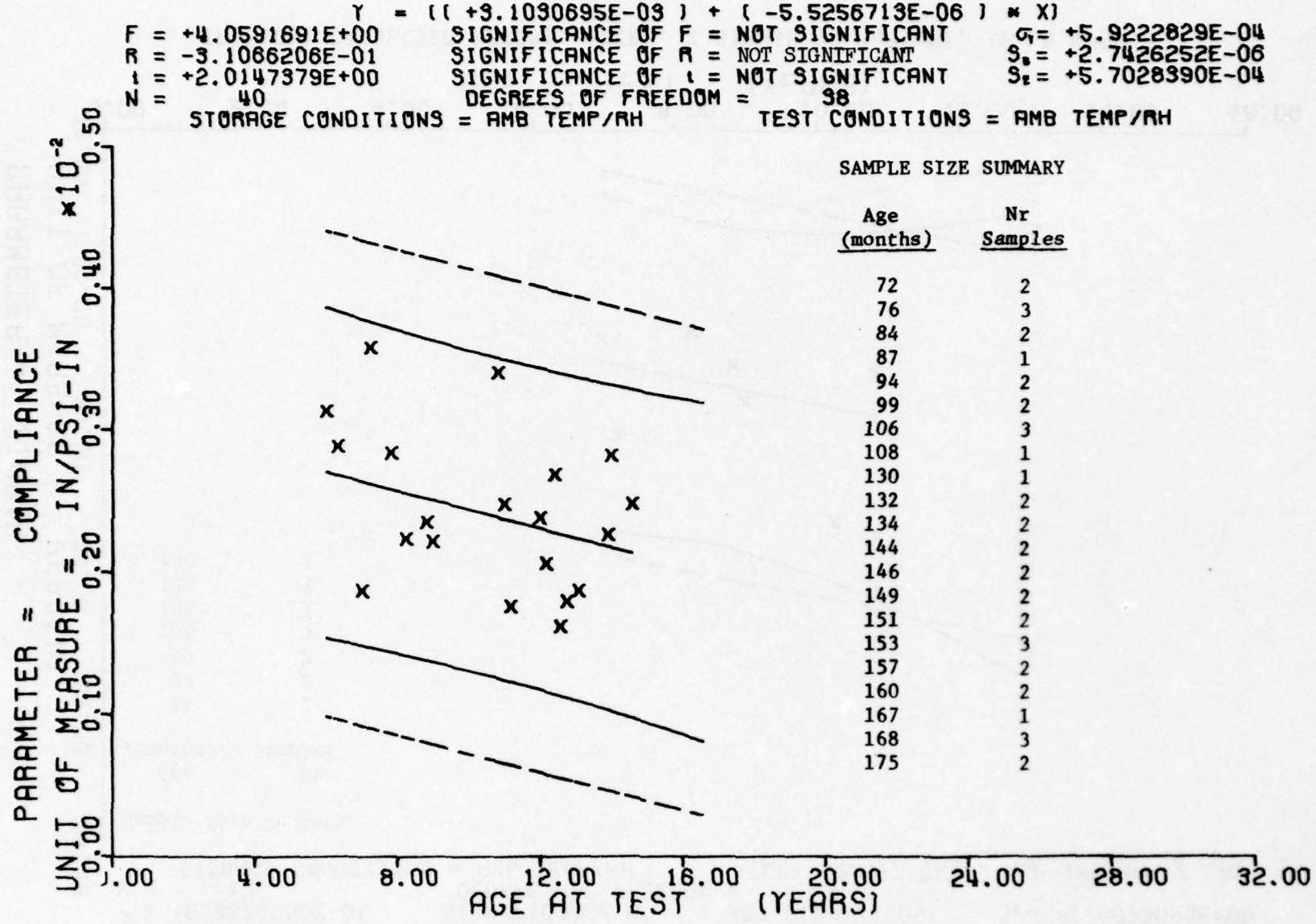
DISSECTED MOTOR TP-H1011, CREEP 12 LB LOAD, COMPLIANCE AT 10 SEC.

Figure 26



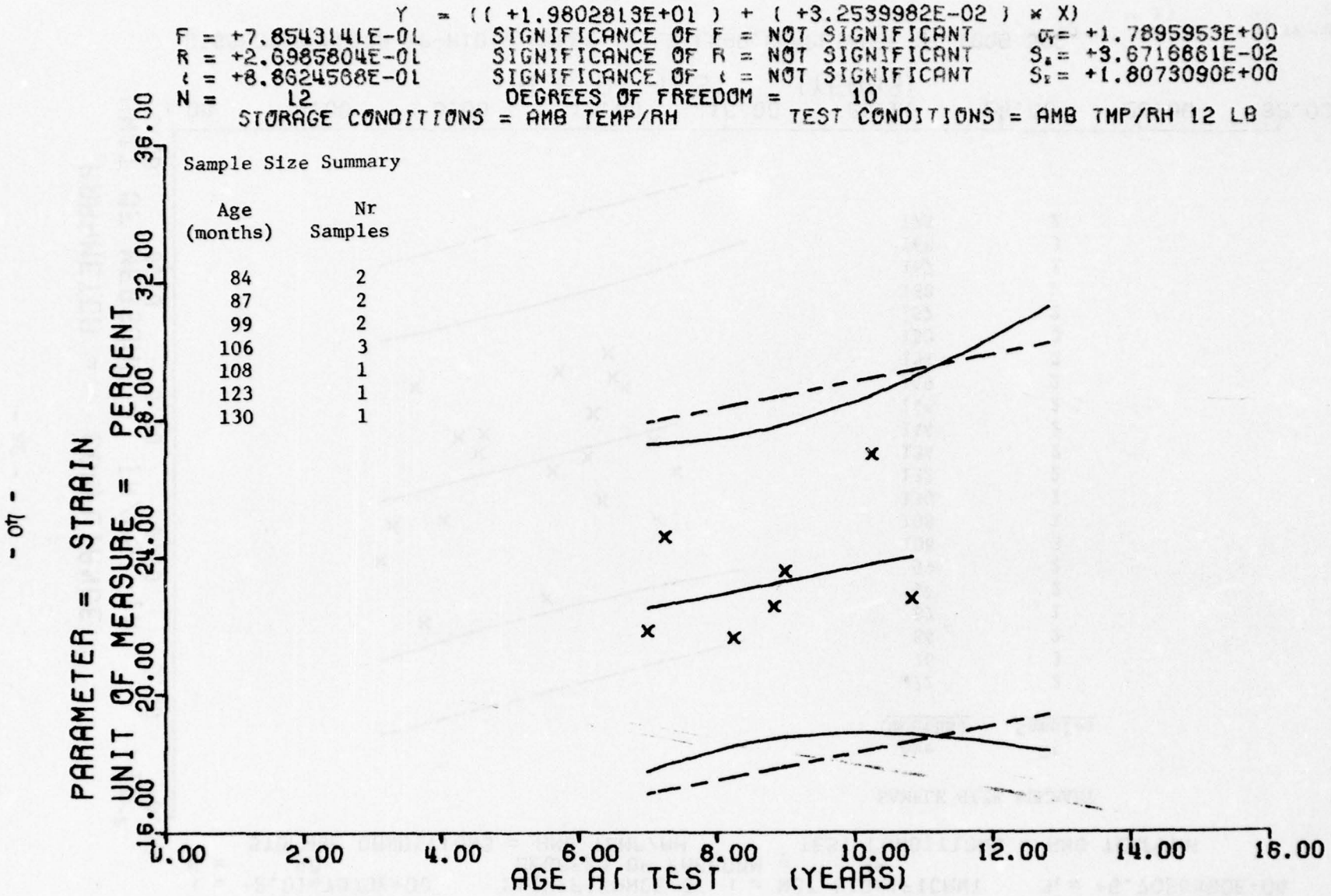
DISSECTED MOTOR TP-H1011, CREEP 12 L6 LOAD, COMPLIANCE AT 20 SEC.

Figure 27



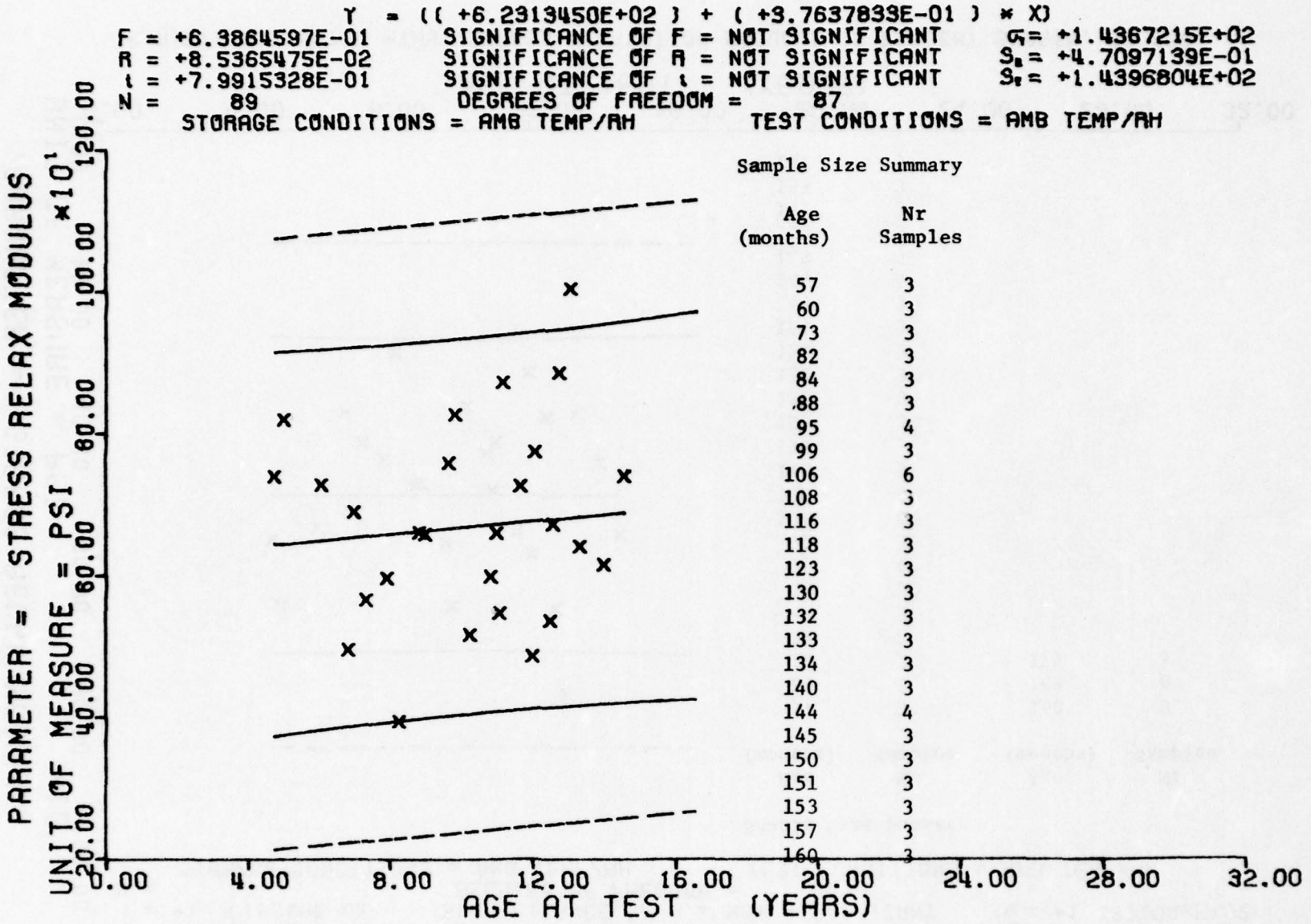
DISSECTED MOTOR TP-H1011, CREEP 12 LB LOAD, COMPLIANCE AT 1000 SEC.

Figure 28



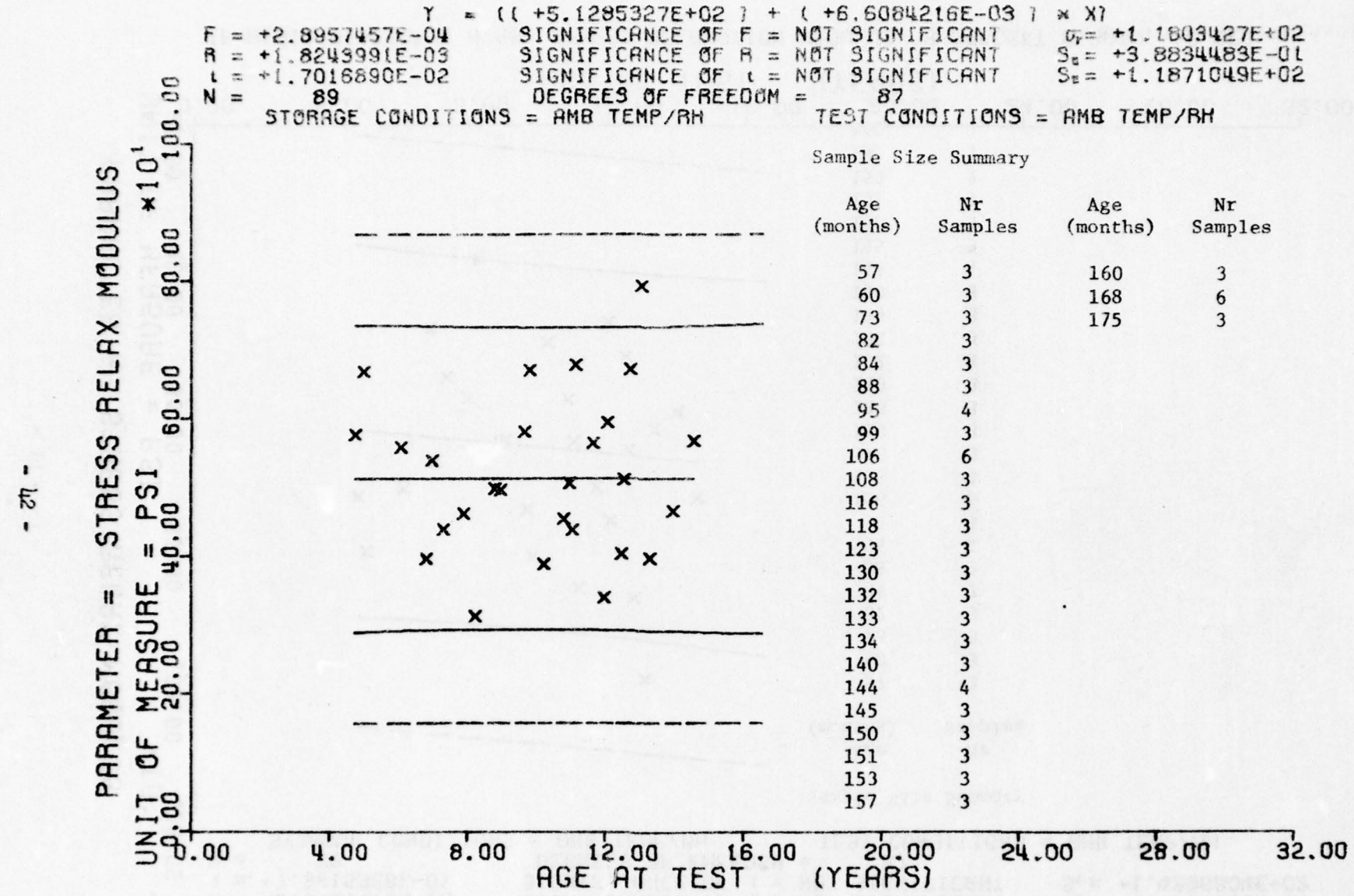
TP-H1011 DISSECTED MOTORS, CREEP, % STRAIN AT RUPTURE, 12 LB LOAD

Figure 29



TP-H1011 DISSECTED MTRS, STRESS RELAXATION MODULUS, 3 PERCENT STRAIN, 10 SEC

Figure 30



TP-H1011 DISSECTED MTRS, STRESS RELAXATION MODULUS, 3 PERCENT STRAIN, 50 SEC

Figure 31

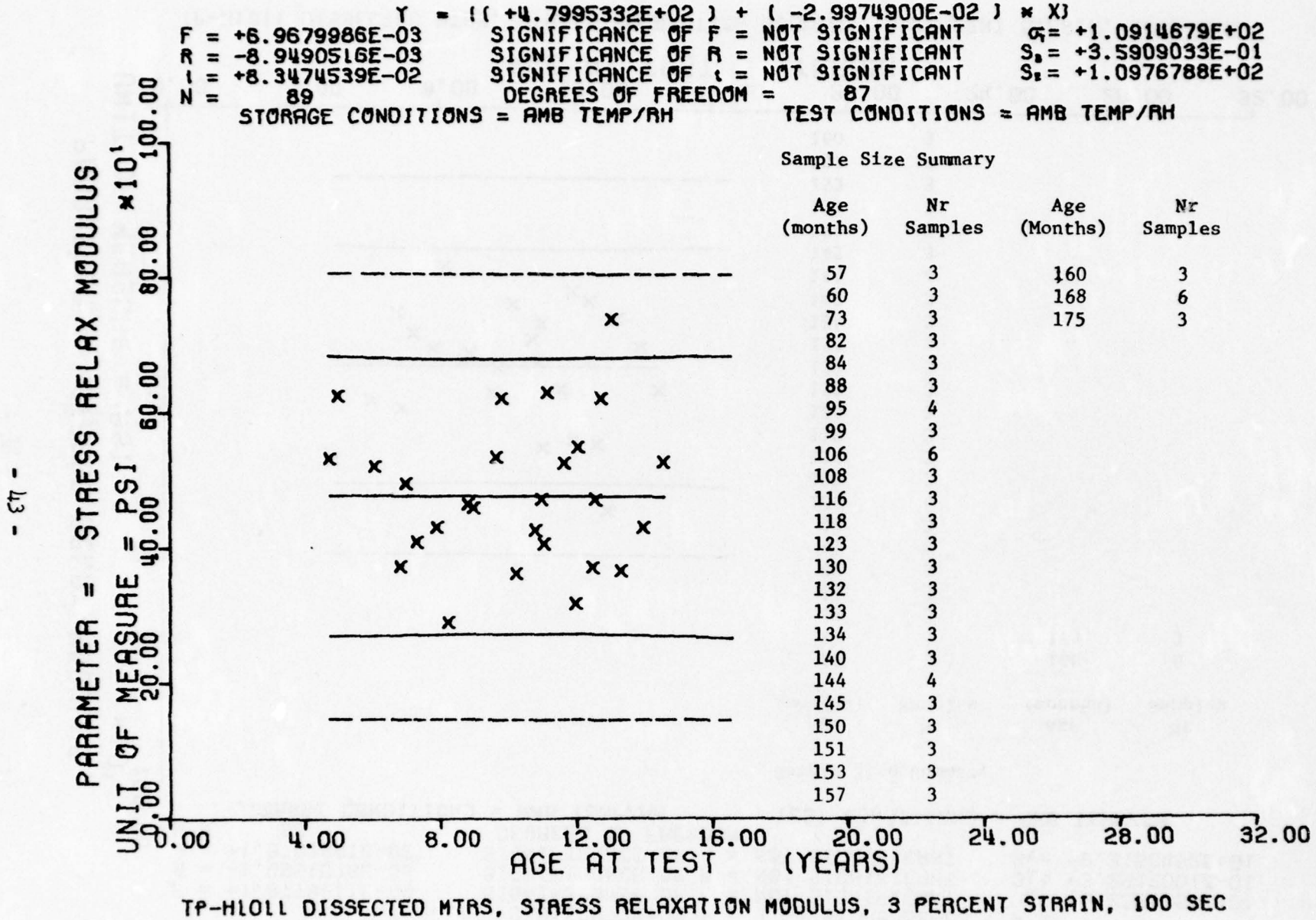
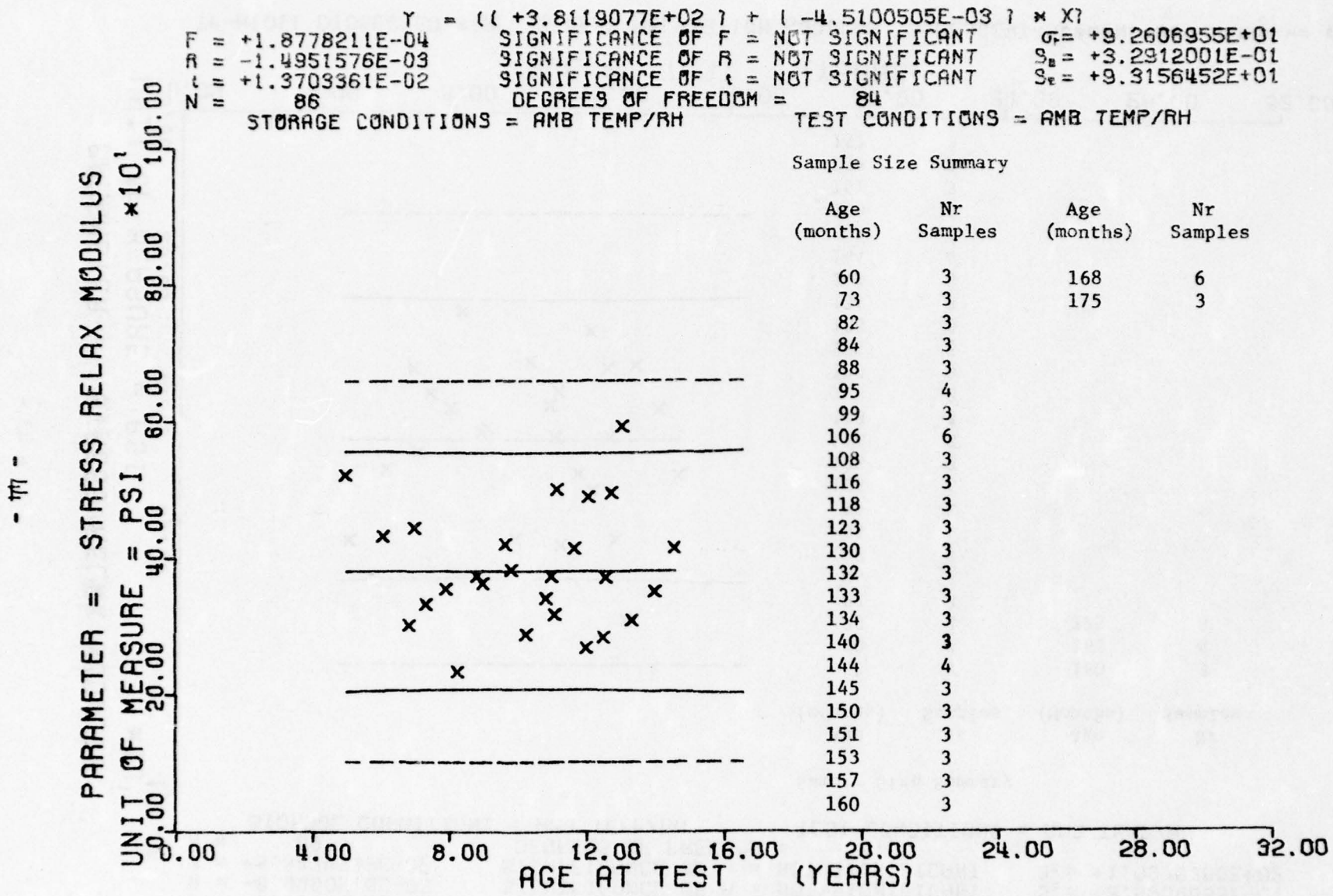

Y = (+4.7995332E+02) + (-2.9974900E-02) * XJ
F = +6.9679986E-03 SIGNIFICANCE OF F = NOT SIGNIFICANT σ = +1.0914679E+02
R = -8.9490516E-03 SIGNIFICANCE OF R = NOT SIGNIFICANT Sa = +3.5909033E-01
t = +8.3474539E-02 SIGNIFICANCE OF t = NOT SIGNIFICANT Sb = +1.0976788E+02
N = 89 DEGREES OF FREEDOM = 87
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples Age (Months) Nr Samples
57 3 160 3
60 3 168 6
73 3 175 3
82 3
84 3
88 3
95 4
99 3
106 6
108 3
116 3
118 3
123 3
130 3
132 3
133 3
134 3
140 3
144 4
145 3
150 3
151 3
153 3
157 3
PARAMETER = STRESS RELAX MODULUS
UNIT OF MEASURE = PSI *10¹
0.00
20.00
40.00
60.00
80.00
100.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
TP-HL011 DISSECTED MTRS, STRESS RELAXATION MODULUS, 3 PERCENT STRAIN, 100 SEC

Figure 32

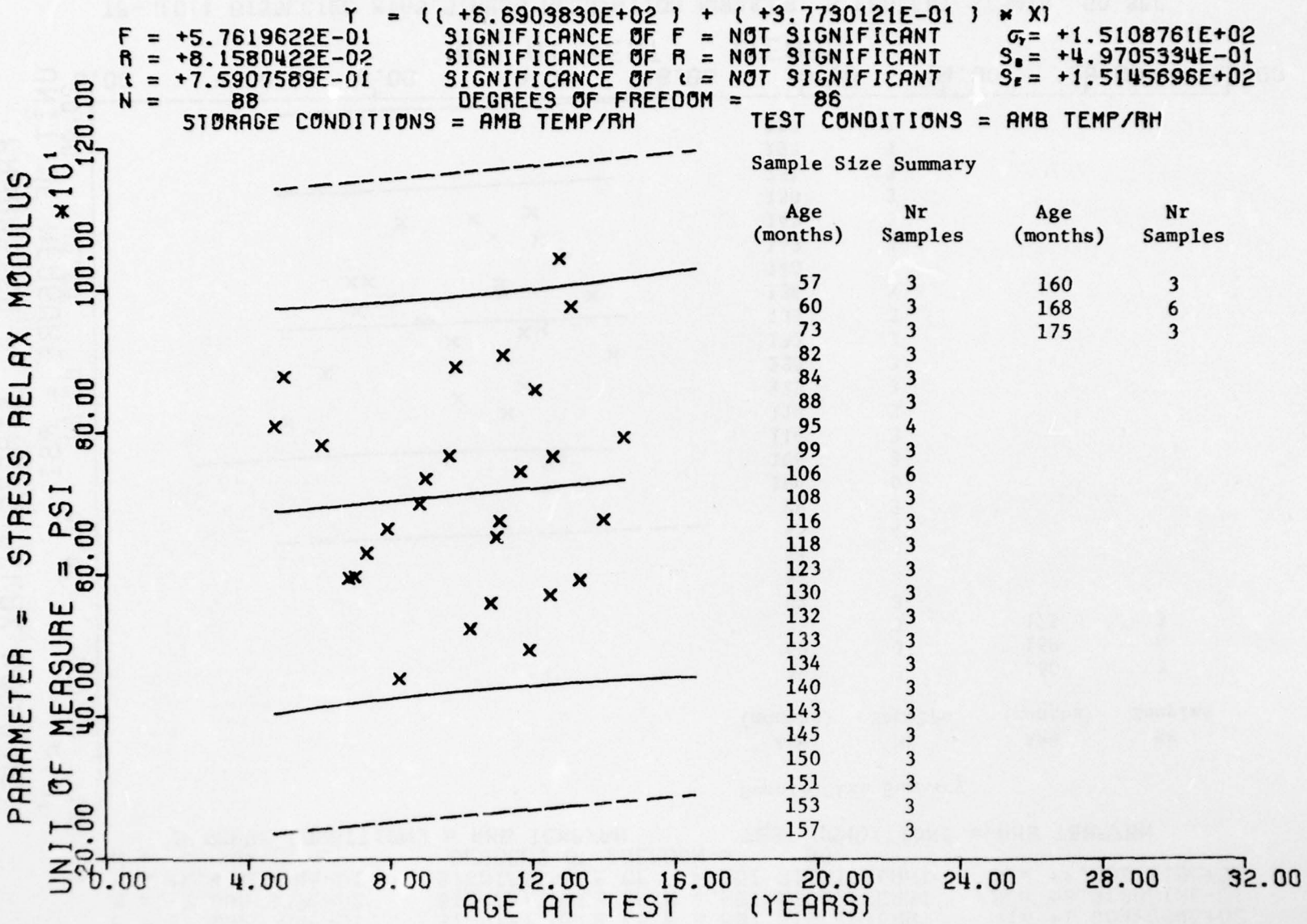


Sample Size Summary

Age (months)	Nr Samples	Age (months)	Nr Samples
60	3	168	6
73	3	175	3
82	3		
84	3		
88	3		
95	4		
99	3		
106	6		
108	3		
116	3		
118	3		
123	3		
130	3		
132	3		
133	3		
134	3		
140	3		
144	4		
145	3		
150	3		
151	3		
153	3		
157	3		
160	3		

TP-H1011 DISSECTED MTRS, STRESS RELAXATION MODULUS, 3 PERCENT STRAIN, 1000 SEC

Figure 33

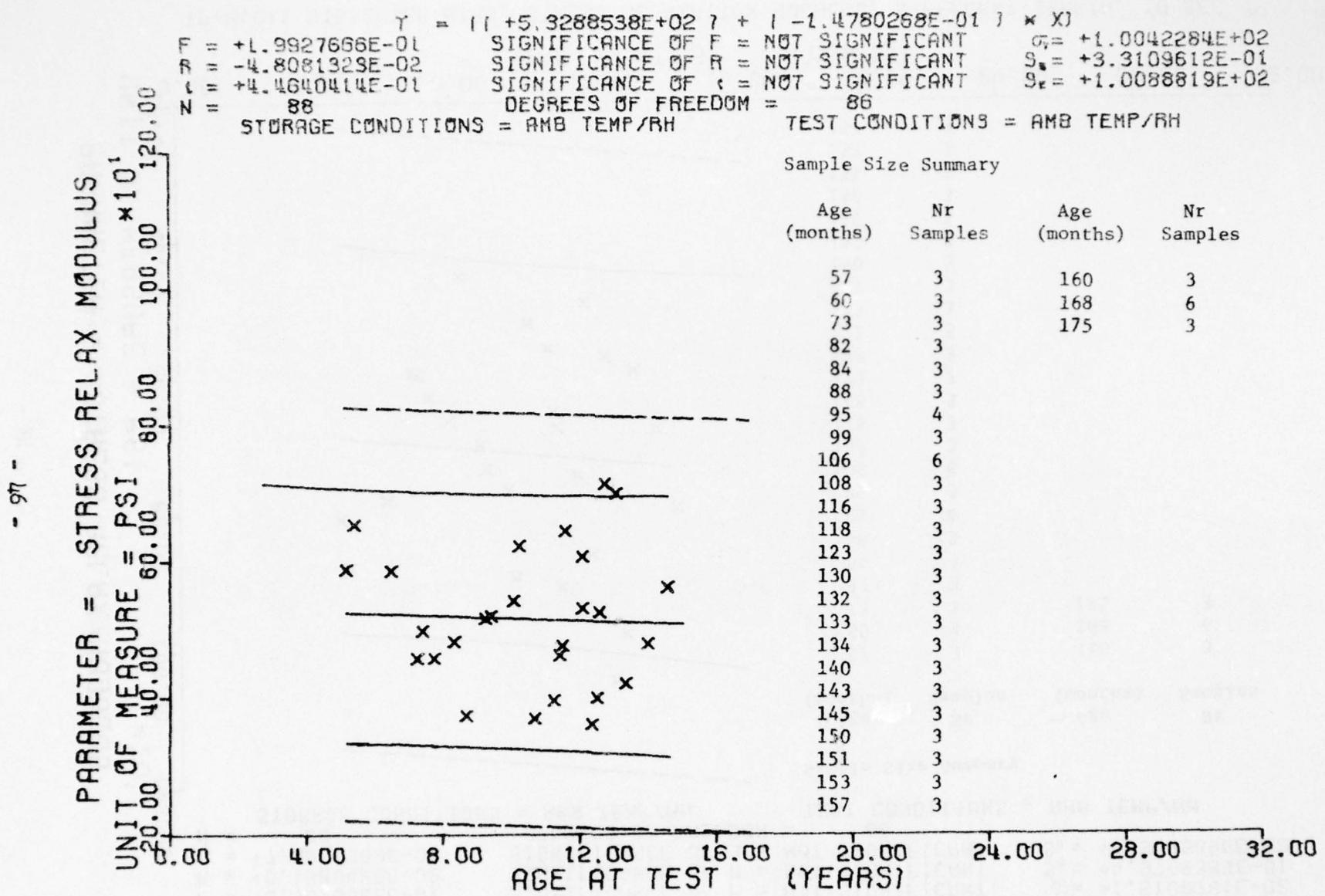


Sample Size Summary

Age (months)	Nr Samples	Age (months)	Nr Samples
57	3	160	3
60	3	168	6
73	3	175	3
82	3		
84	3		
88	3		
95	4		
99	3		
106	6		
108	3		
116	3		
118	3		
123	3		
130	3		
132	3		
133	3		
134	3		
140	3		
143	3		
145	3		
150	3		
151	3		
153	3		
157	3		

TP-H1011 DISSECTED MTRS, STRESS RELAXATION MODULUS, 5 PERCENT STRAIN, 10 SEC

Figure 34

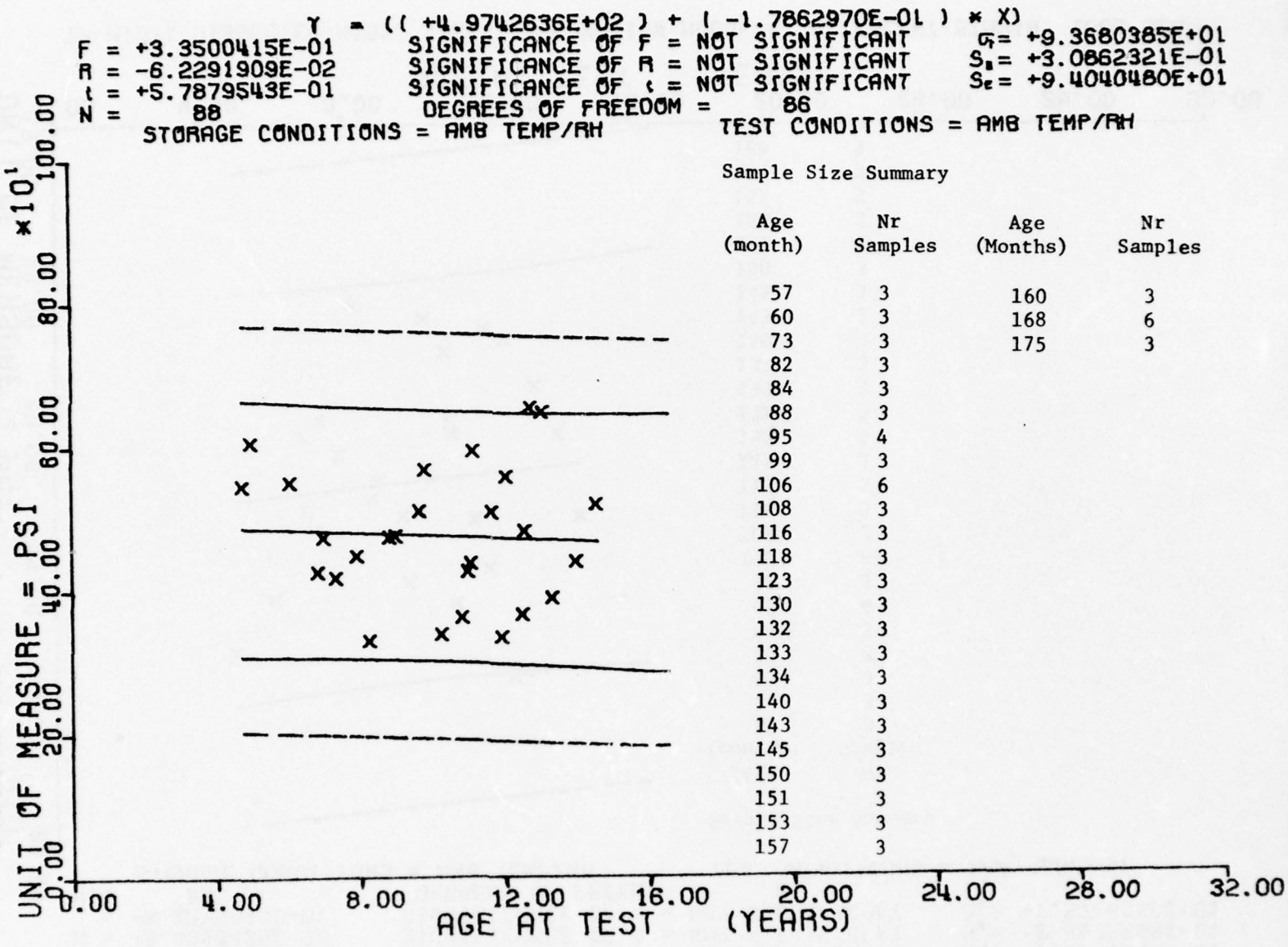


Sample Size Summary

Age (months)	Nr Samples	Age (months)	Nr Samples
57	3	160	3
60	3	168	6
73	3	175	3
82	3		
84	3		
88	3		
95	4		
99	3		
106	6		
108	3		
116	3		
118	3		
123	3		
130	3		
132	3		
133	3		
134	3		
140	3		
143	3		
145	3		
150	3		
151	3		
153	3		
157	3		

TP-H1011 DISSECTED MTRS, STRESS RELAXATION MODULUS, 5 PERCENT STRAIN, 50 SEC

Figure 35

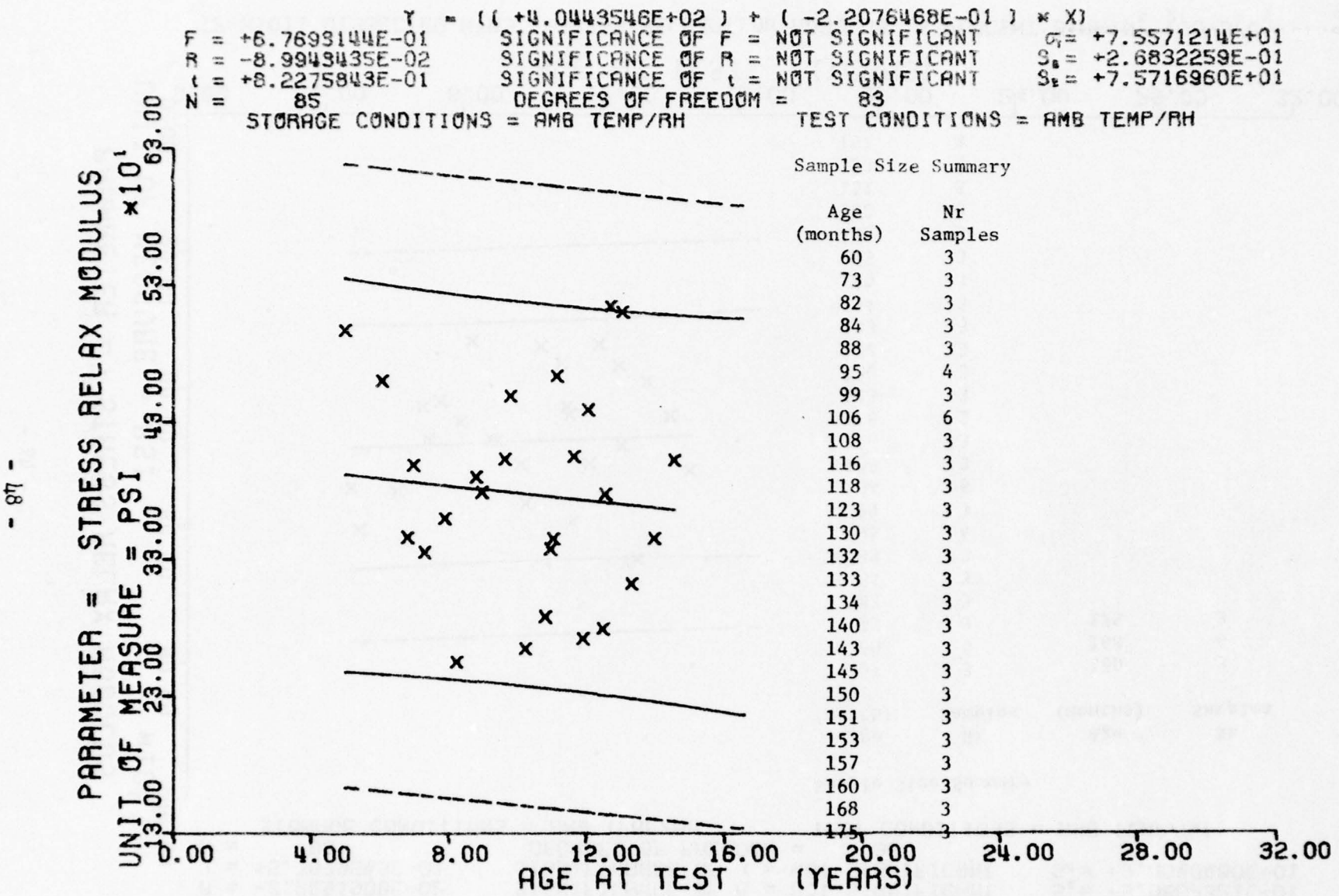


Sample Size Summary

Age (month)	Nr Samples	Age (Months)	Nr Samples
57	3	160	3
60	3	168	6
73	3	175	3
82	3		
84	3		
88	3		
95	4		
99	3		
106	6		
108	3		
116	3		
118	3		
123	3		
130	3		
132	3		
133	3		
134	3		
140	3		
143	3		
145	3		
150	3		
151	3		
153	3		
157	3		

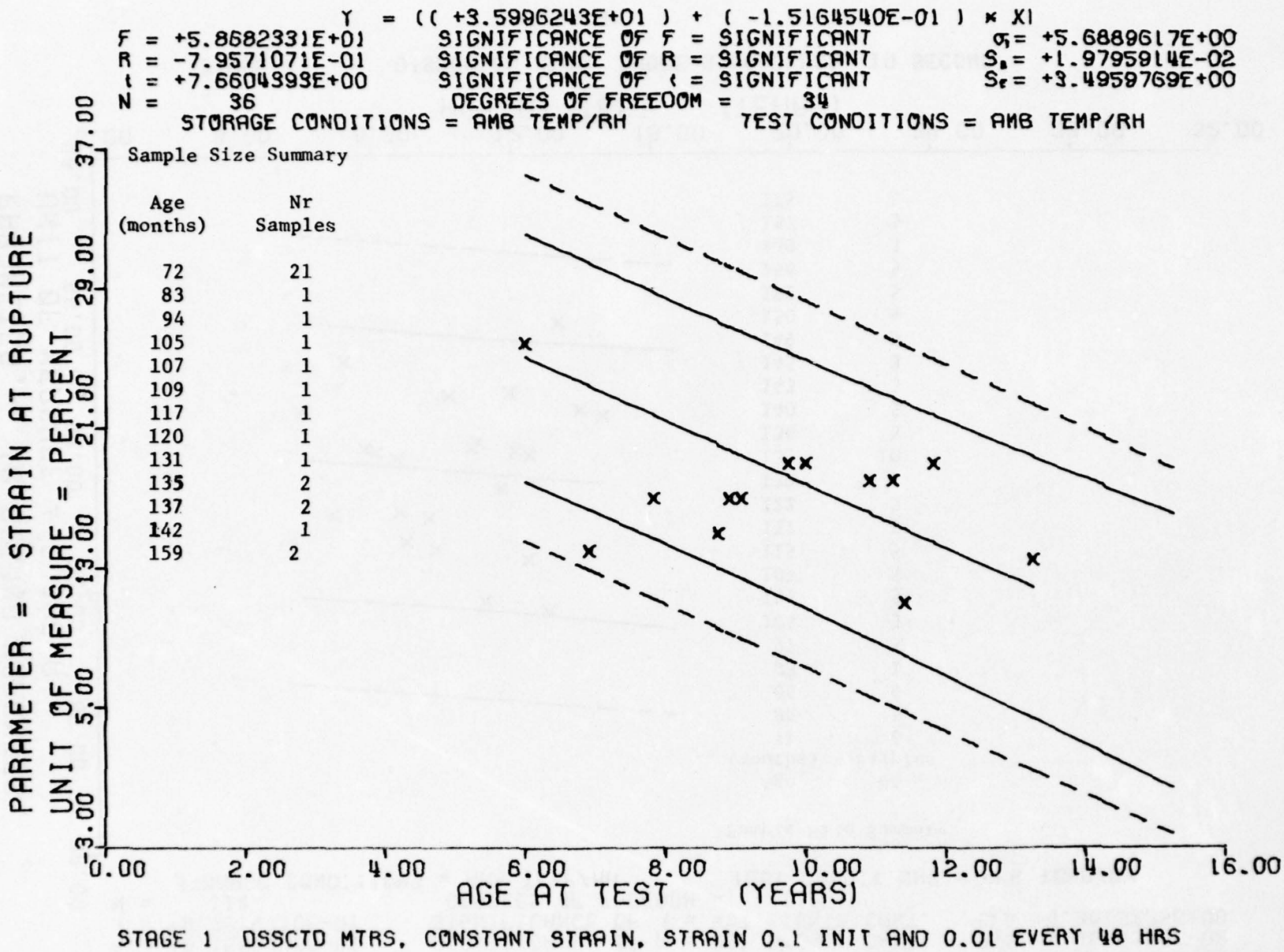
TP-H1011 DISSECTED MTRS, STRESS RELAXATION MODULUS, 5 PERCENT STRAIN, 100 SEC

Figure 36



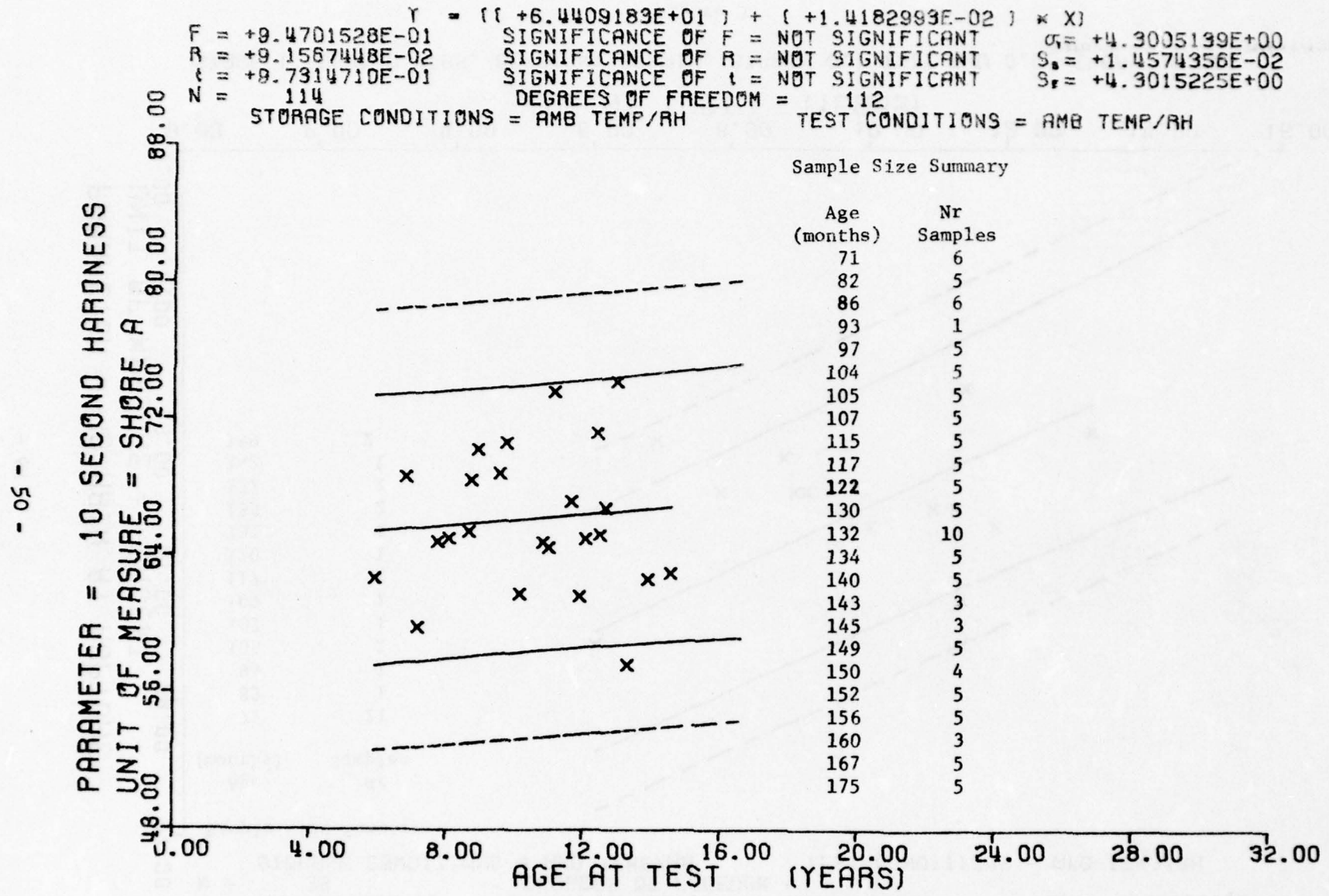
TP-H1011 DISSECTED MTRS, STRESS RELAXATION MODULUS, 5 PERCENT STRAIN, 1000 SEC

Figure 37



STAGE 1 DSSCTD MTRS, CONSTANT STRAIN, STRAIN 0.1 INIT AND 0.01 EVERY 48 HRS

Figure 38



STAGE 1 DISSECTED MTRS, SHORE A HARDNESS, 10 SECOND

Figure 39

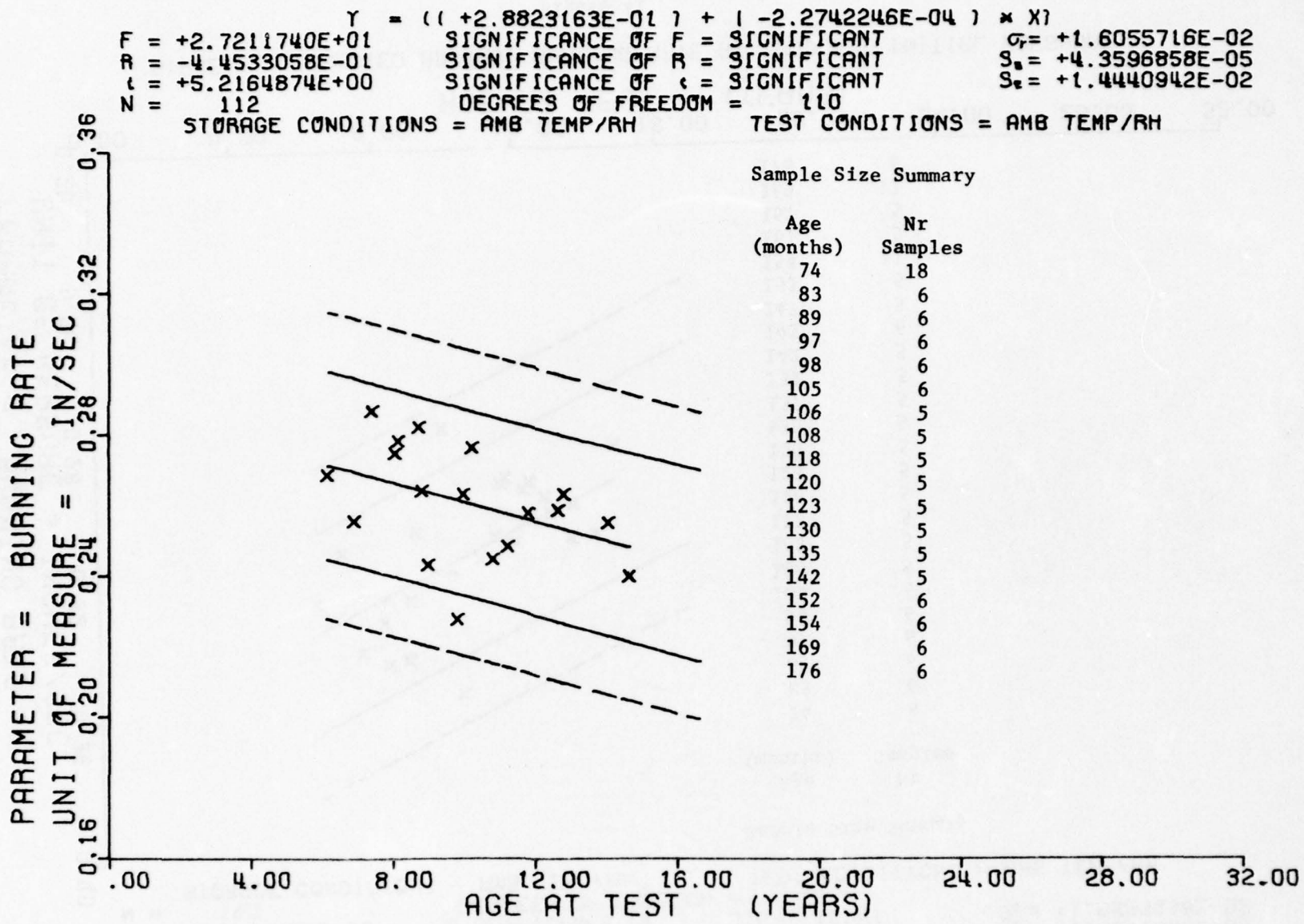

Y = ((+2.8823163E-01) + (-2.2742246E-04) * X)
F = +2.7211740E+01 SIGNIFICANCE OF F = SIGNIFICANT σr= +1.6055716E-02
R = -4.4533058E-01 SIGNIFICANCE OF R = SIGNIFICANT Sa= +4.3596858E-05
t = +5.2164874E+00 SIGNIFICANCE OF t = SIGNIFICANT Se= +1.4440942E-02
N = 112 DEGREES OF FREEDOM = 110
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples
74 18
83 6
89 6
97 6
98 6
105 6
106 5
108 5
118 5
120 5
123 5
130 5
135 5
142 5
152 6
154 6
169 6
176 6
PARAMETER = BURNING RATE
UNIT OF MEASURE = IN/SEC
0.16
0.20
0.24
0.28
0.32
0.36
.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
STAGE 1 DISSECTED MOTORS, BURNING RATE AT 500 PSI INITIAL PRESSURE

Figure 40

Y = ((+3.6677714E-01) + (-4.1194159E-04) * X)

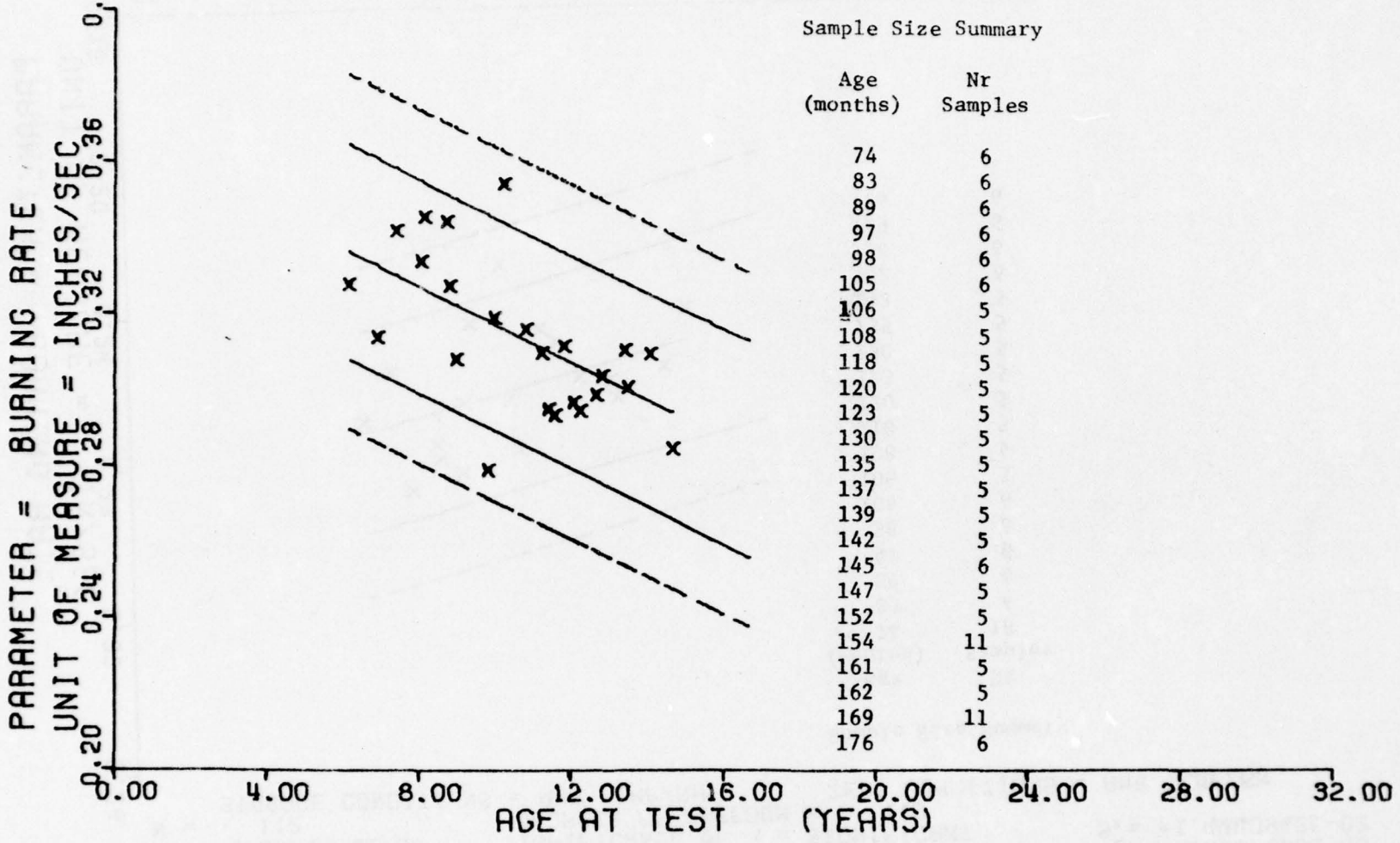
F = +8.2885778E+01 SIGNIFICANCE OF F = SIGNIFICANT σ_r = +1.9571331E-02

R = -6.1257057E-01 SIGNIFICANCE OF R = SIGNIFICANT S_b = +4.5247609E-05

t = +9.1041626E+00 SIGNIFICANCE OF t = SIGNIFICANT S_Y = +1.5525438E-02

N = 140 DEGREES OF FREEDOM = 138

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH

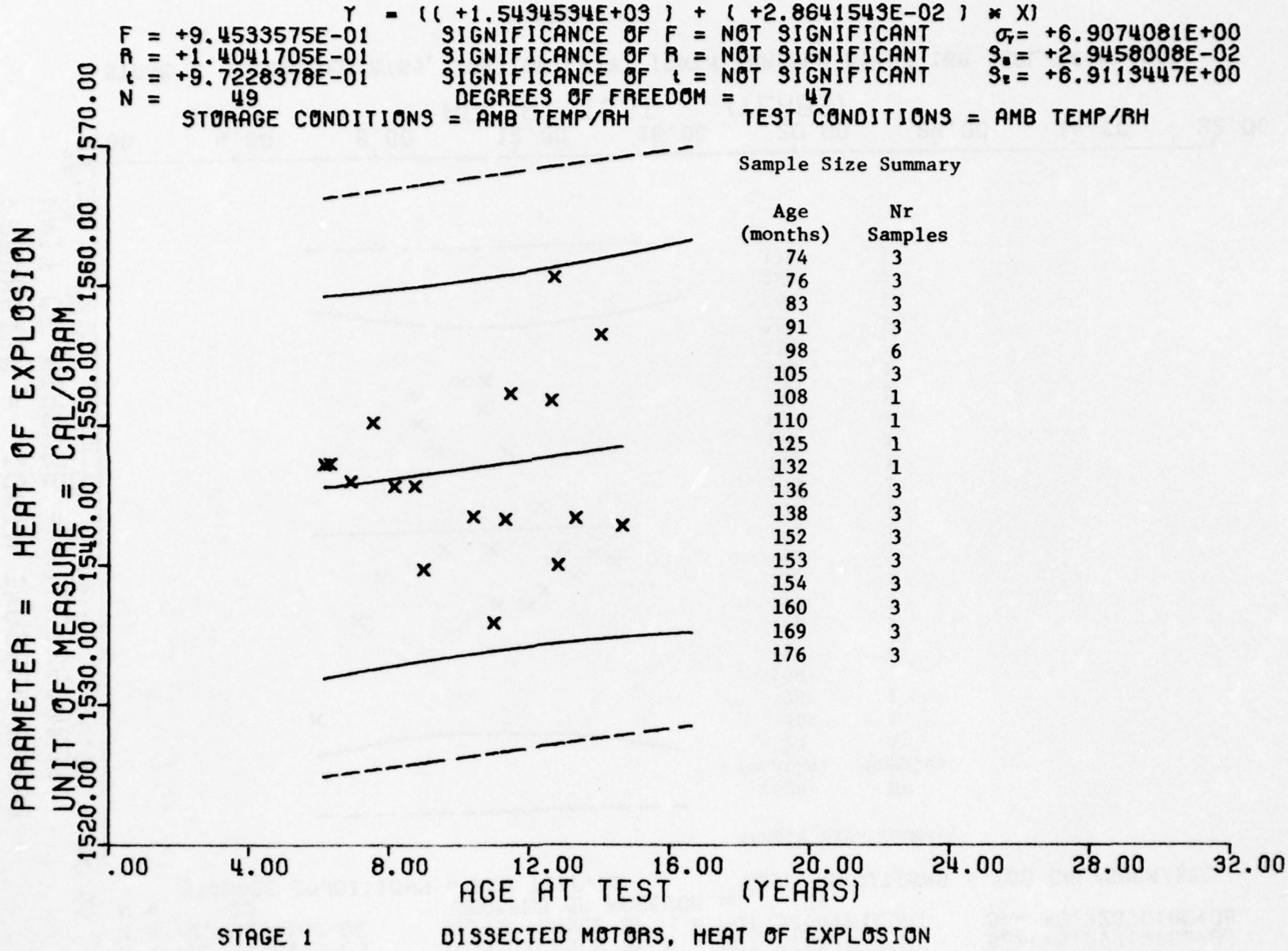


Sample Size Summary

Age (months)	Nr Samples
74	6
83	6
89	6
97	6
98	6
105	6
106	5
108	5
118	5
120	5
123	5
130	5
135	5
137	5
139	5
142	5
145	6
147	5
152	5
154	11
161	5
162	5
169	11
176	6

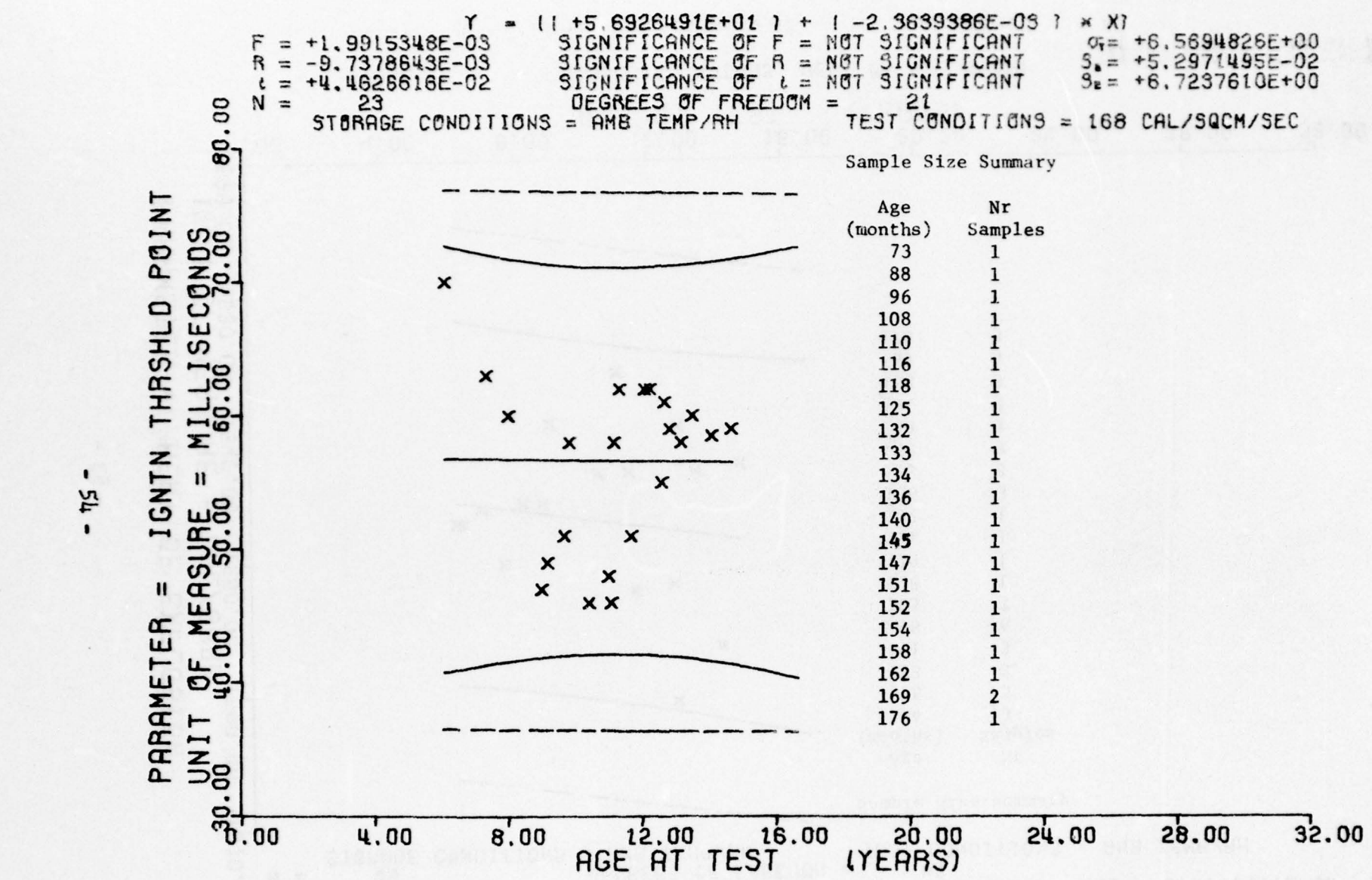
STAGE 1 DISSECTED MOTORS, BURNING RATE AT 1000 PSI INITIAL PRESSURE

Figure 41



STAGE 1 DISSECTED MOTORS, HEAT OF EXPLOSION

Figure 42

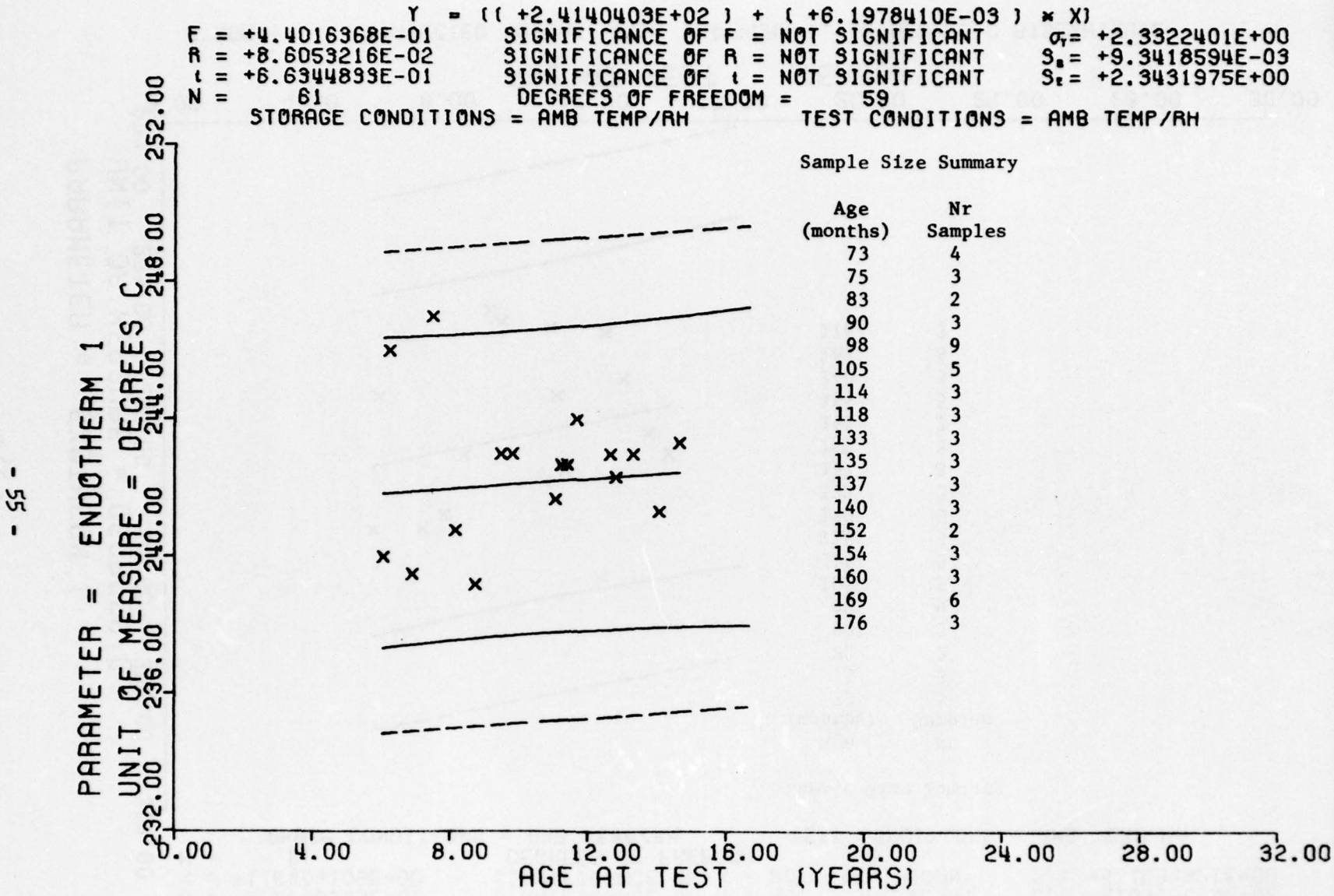


Sample Size Summary

Age (months)	Nr Samples
73	1
88	1
96	1
108	1
110	1
116	1
118	1
125	1
132	1
133	1
134	1
136	1
140	1
145	1
147	1
151	1
152	1
154	1
158	1
162	1
169	2
176	1

STAGE 1 DISSECTED MTRS, IGNITABILITY, IGNTN THRSHLD POINT 168 (CAL/SQCM)/SEC

Figure 43



STAGE 1 DISSECTED MOTORS, DTA, ENDOTHERM 1, 12 DEGREE C RISE/MINUTE

Figure 44

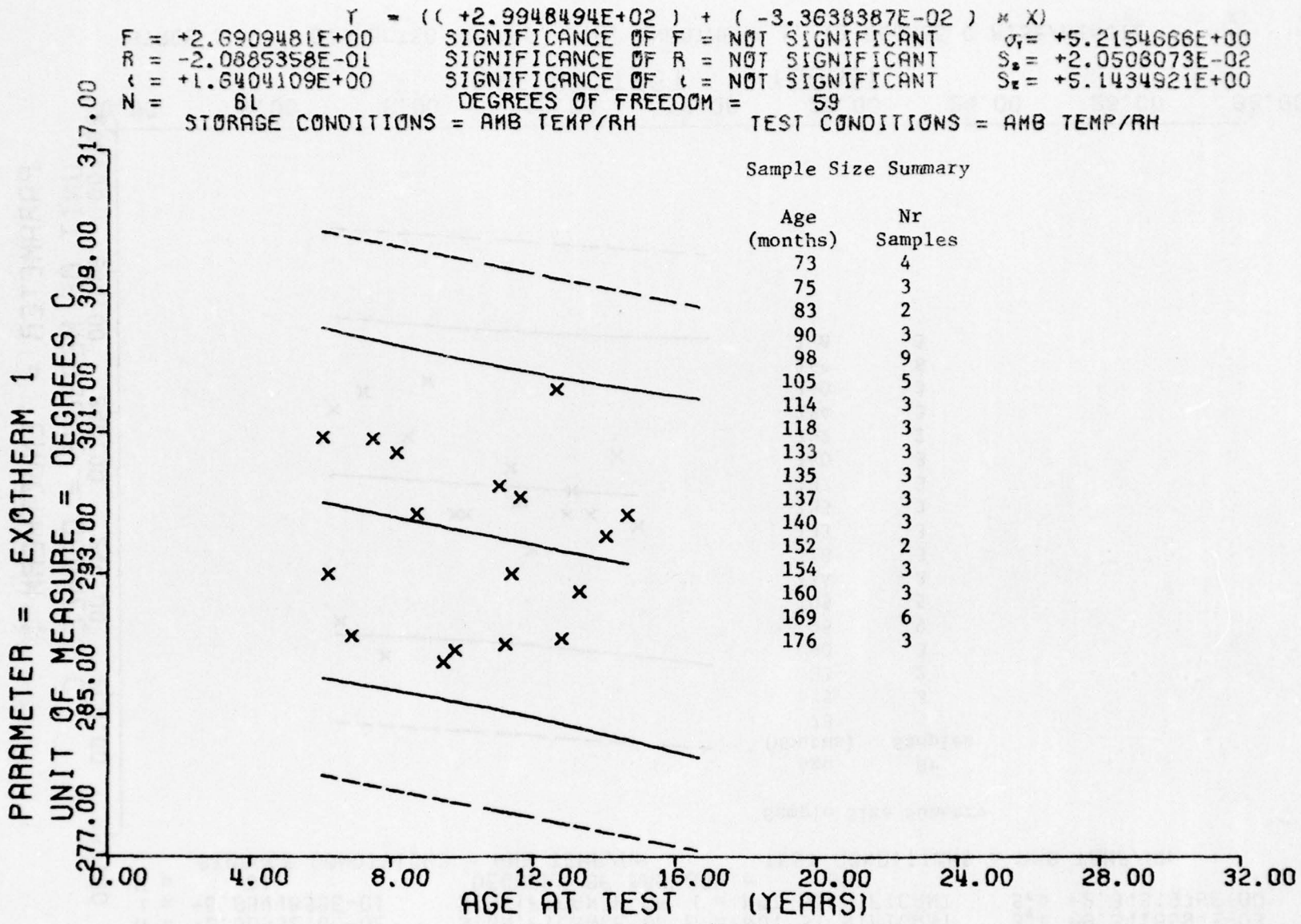

Y = ((+2.9948494E+02) + (-3.3638387E-02) * X)
F = +2.6909481E+00 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_Y = +5.2154666E+00
R = -2.0885358E-01 SIGNIFICANCE OF R = NOT SIGNIFICANT S_B = +2.0508073E-02
t = +1.6404109E+00 SIGNIFICANCE OF t = NOT SIGNIFICANT S_E = +5.1434921E+00
N = 61 DEGREES OF FREEDOM = 59
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples
73 4
75 3
83 2
90 3
98 9
105 5
114 3
118 3
133 3
135 3
137 3
140 3
152 2
154 3
160 3
169 6
176 3
PARAMETER = EXOTHERM 1
UNIT OF MEASURE = DEGREES C
277.00
285.00
293.00
301.00
309.00
317.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
STAGE 1 DISSECTED MOTORS, DTA, EXOTHERM 1, 12 DEGREE C RISE/MINUTE

Figure 45

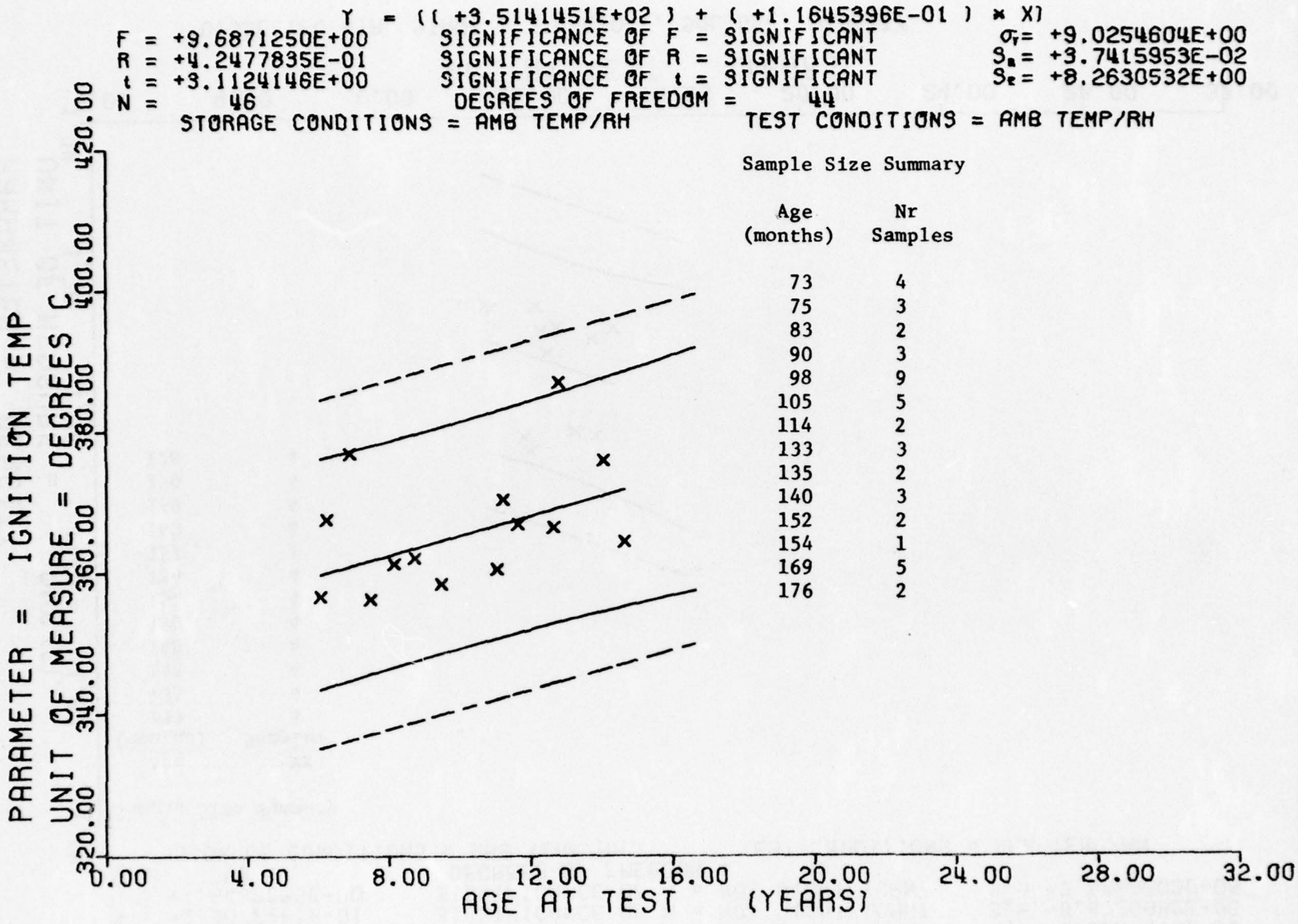

Y = ((+3.5141451E+02) + (+1.1645396E-01) * X)
F = +9.6871250E+00 SIGNIFICANCE OF F = SIGNIFICANT σY= +9.0254604E+00
R = +4.2477835E-01 SIGNIFICANCE OF R = SIGNIFICANT Sa= +3.7415953E-02
t = +3.1124146E+00 SIGNIFICANCE OF t = SIGNIFICANT Se= +8.2630532E+00
N = 46 DEGREES OF FREEDOM = 44
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples
73 4
75 3
83 2
90 3
98 9
105 5
114 2
133 3
135 2
140 3
152 2
154 1
169 5
176 2
PARAMETER = IGNITION TEMP
UNIT OF MEASURE = DEGREES C
320.00
340.00
360.00
380.00
400.00
420.00
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
STAGE 1 DISSECTED MOTORS, DTA IGNITION TEMP, 12 DEG C RISE/MINUTE

Figure 46

Y = ((+1.7522825E+00) + (+1.4622768E-04) * X)

F = +2.7161128E+00 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_1 = +8.0287415E-03

R = +2.3612261E-01 SIGNIFICANCE OF R = NOT SIGNIFICANT S_a = +8.8726982E-05

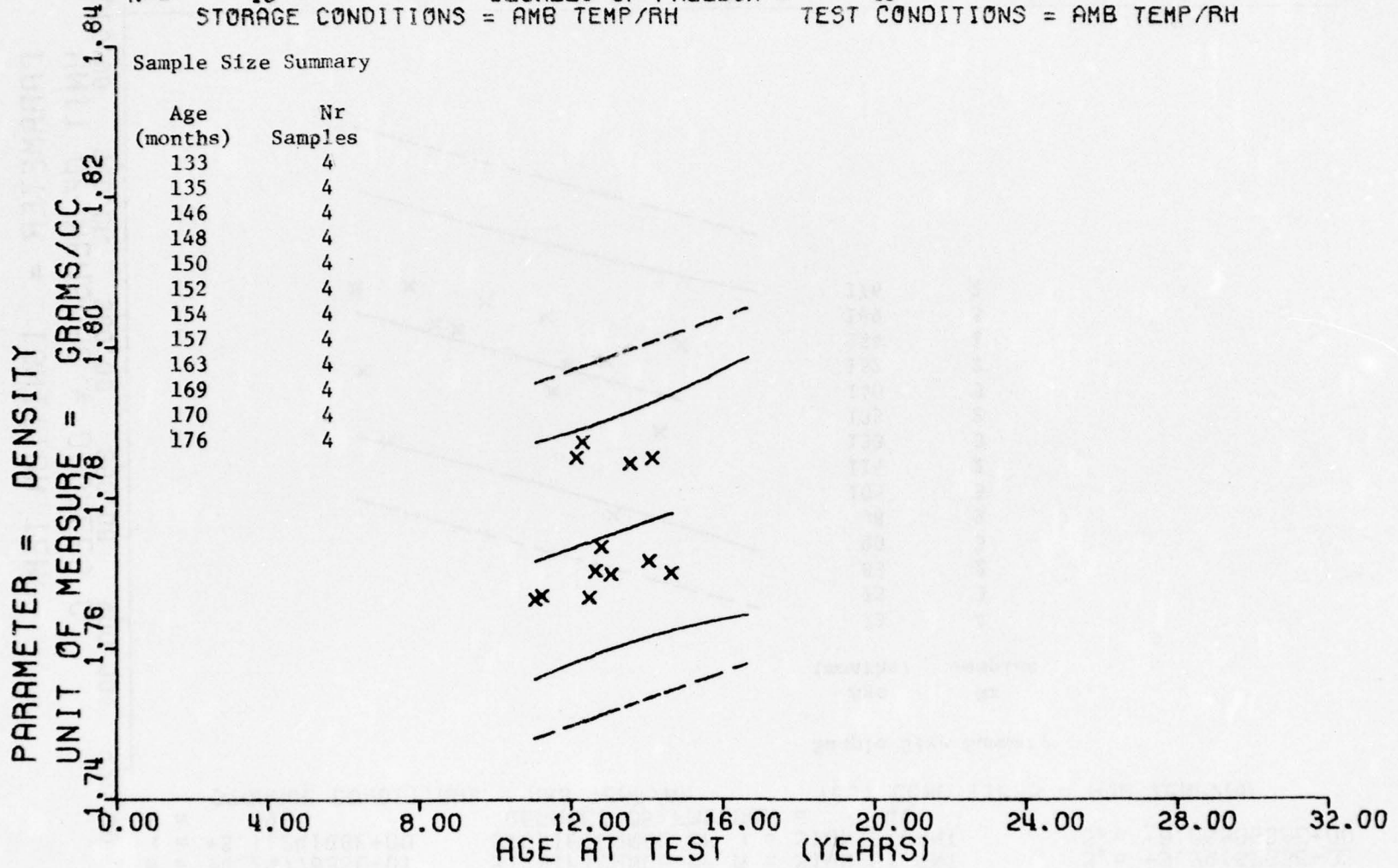
t = +1.6480633E+00 SIGNIFICANCE OF t = NOT SIGNIFICANT S_e = +7.8860603E-03

N = 48 DEGREES OF FREEDOM = 46

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH

Sample Size Summary

Age (months)	Nr Samples
133	4
135	4
146	4
148	4
150	4
152	4
154	4
157	4
163	4
169	4
170	4
176	4



DISSECTED MTR, STAGE 1, TP-H1011, SOL GEL, DENSITY

Figure 47

Y = ((+3.9051904E+00) + (-1.1704048E-03) × X)

F = +3.3999643E-01 SIGNIFICANCE OF F = NOT SIGNIFICANT σ_r = +1.7714642E-01

R = -8.5658275E-02 SIGNIFICANCE OF R = NOT SIGNIFICANT S_b = +2.0072383E-03

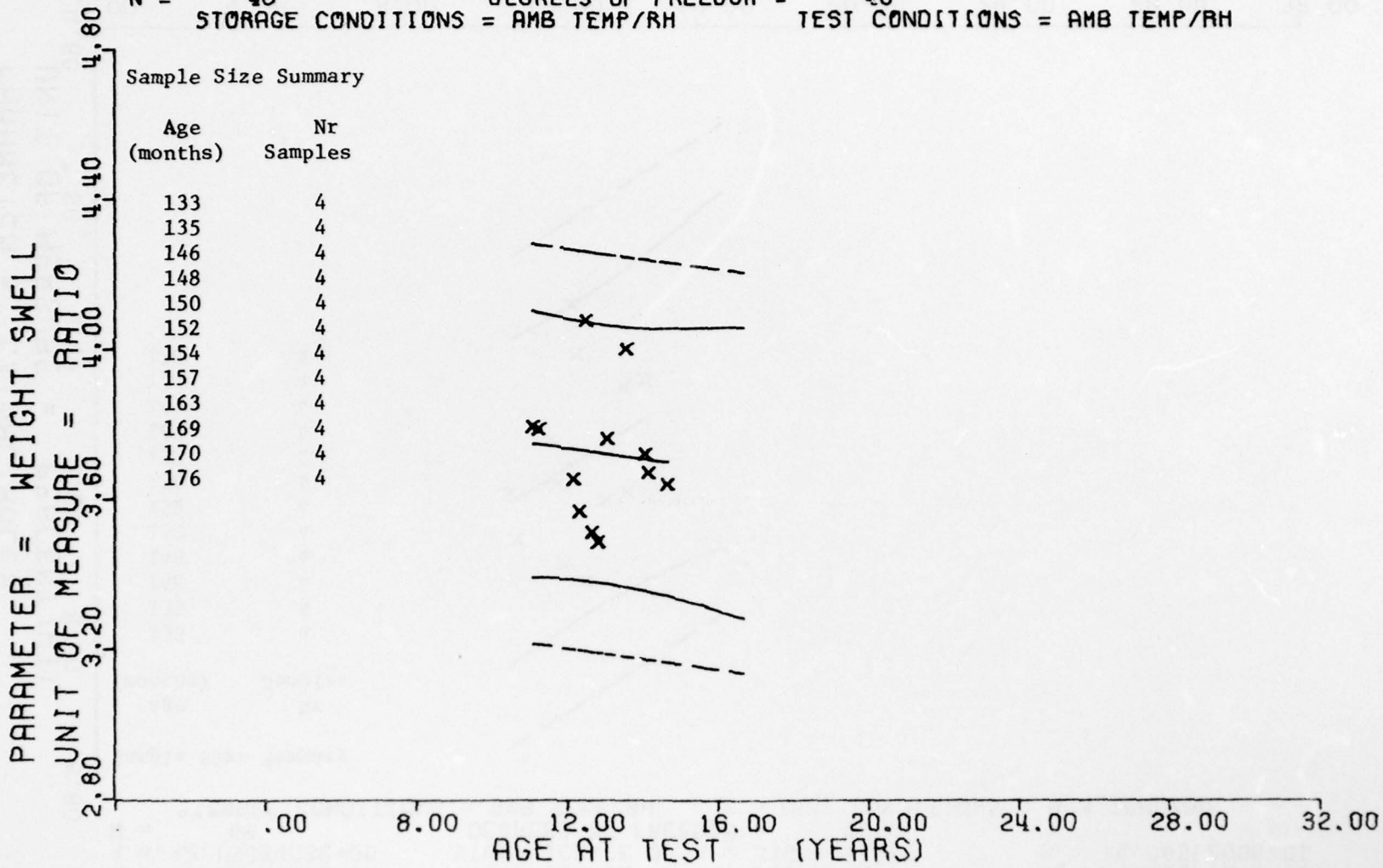
t = +5.8309213E-01 SIGNIFICANCE OF t = NOT SIGNIFICANT S_x = +1.7840347E-01

N = 48 DEGREES OF FREEDOM = 46

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH

Sample Size Summary

Age (months)	Nr Samples
133	4
135	4
146	4
148	4
150	4
152	4
154	4
157	4
163	4
169	4
170	4
176	4



DISSECTED MTR. STAGE 1, TP-HL011, SOL GEL, GEL SWELL RATIO

Figure 48

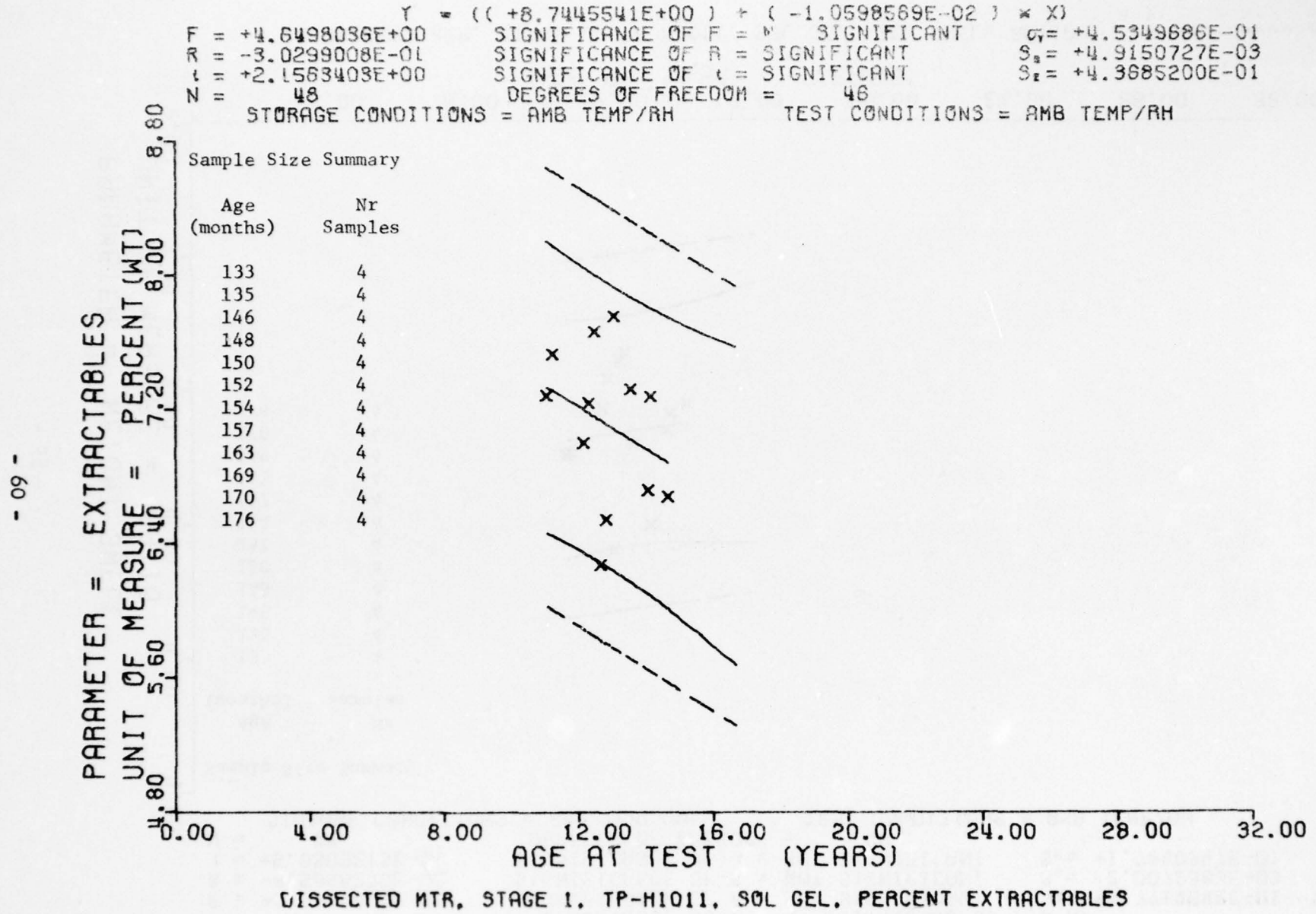

Y = ((+8.7445541E+00) + (-1.0598569E-02) * X)
F = +4.6498036E+00 SIGNIFICANCE OF F = N SIGNIFICANT σ1= +4.5349686E-01
R = -3.0299008E-01 SIGNIFICANCE OF R = SIGNIFICANT Sa= +4.9150727E-03
t = +2.1563403E+00 SIGNIFICANCE OF t = SIGNIFICANT Sz= +4.3685200E-01
N = 48 DEGREES OF FREEDOM = 46
STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH
Sample Size Summary
Age (months) Nr Samples
133 4
135 4
146 4
148 4
150 4
152 4
154 4
157 4
163 4
169 4
170 4
176 4
PARAMETER = EXTRACTABLES
UNIT OF MEASURE = PERCENT (WT)
8.80
8.00
7.20
6.40
5.60
4.80
0.00
4.00
8.00
12.00
16.00
20.00
24.00
28.00
32.00
AGE AT TEST (YEARS)
DISSECTED MTR, STAGE 1, TP-H1011, SOL GEL, PERCENT EXTRACTABLES

Figure 49

Y = ((+1.7406743E-02) + (-4.5158888E-05) * X)

F = +7.4247527E+00 SIGNIFICANCE OF F = SIGNIFICANT σ_r = +1.5704675E-03

R = -3.7279470E-01 SIGNIFICANCE OF R = SIGNIFICANT S_a = +1.6573042E-05

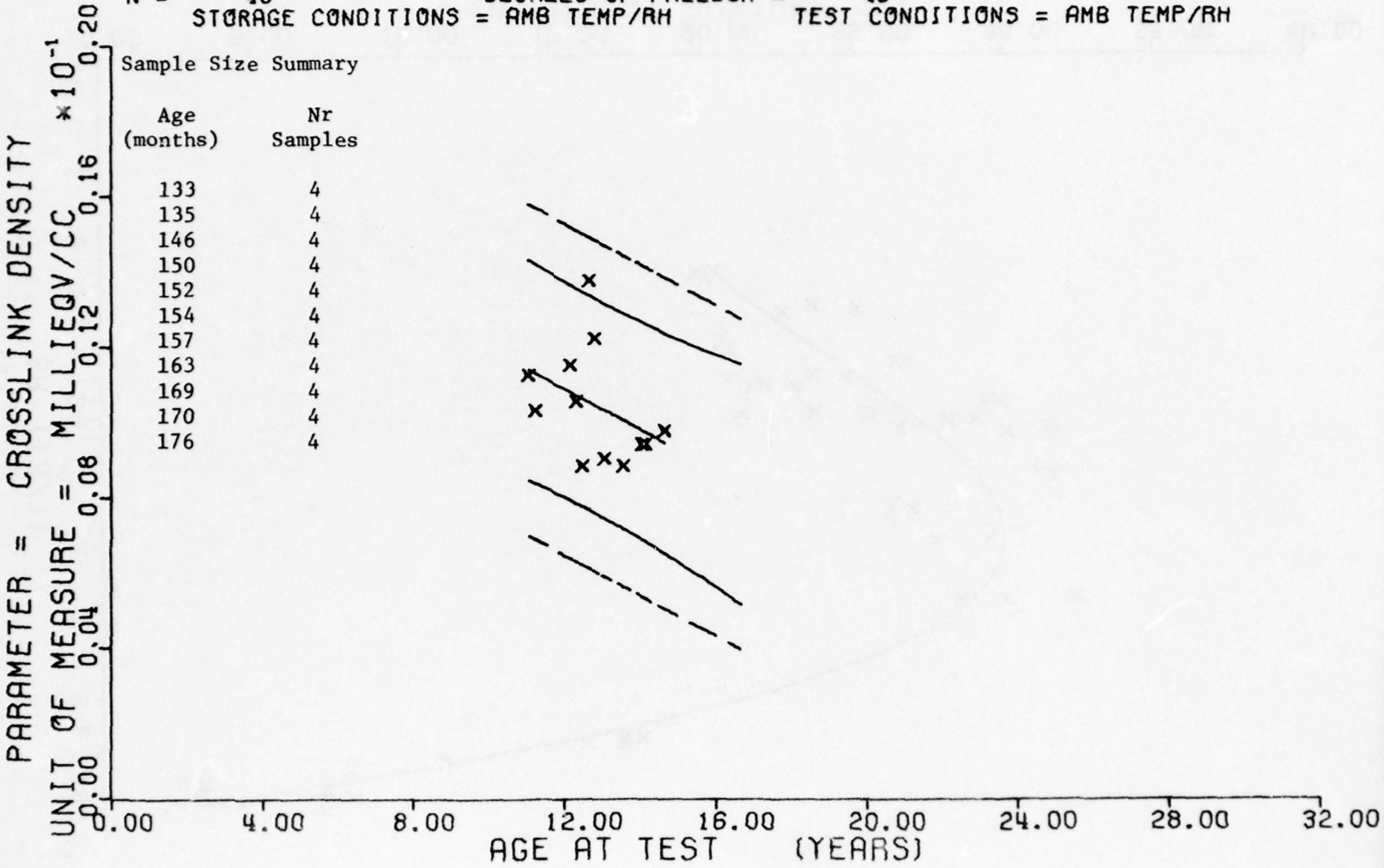
t = +2.7248399E+00 SIGNIFICANCE OF t = SIGNIFICANT S_t = +1.4730131E-03

N = 48 DEGREES OF FREEDOM = 46

STORAGE CONDITIONS = AMB TEMP/RH TEST CONDITIONS = AMB TEMP/RH

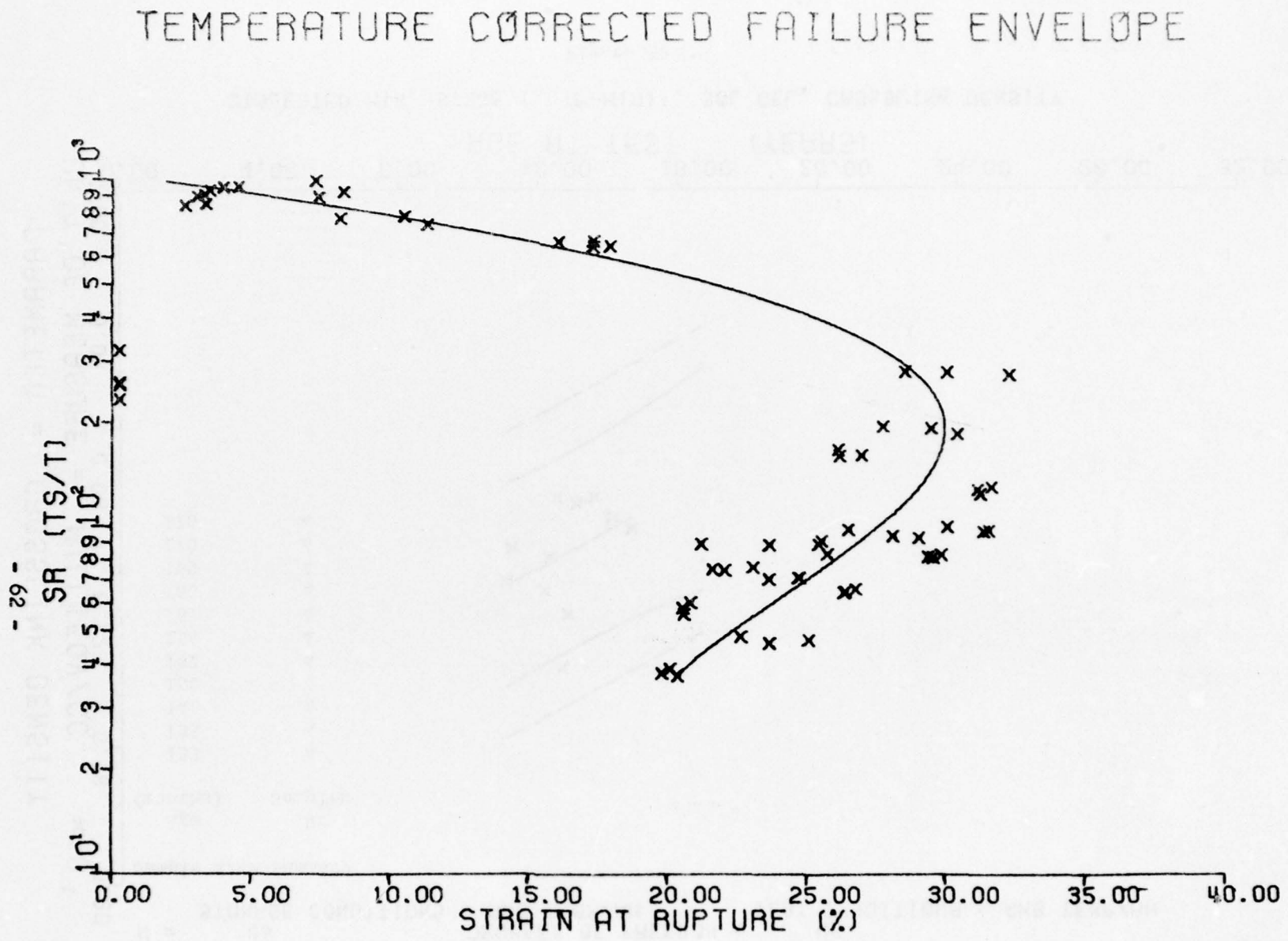
Sample Size Summary

Age (months)	Nr Samples
133	4
135	4
146	4
150	4
152	4
154	4
157	4
163	4
169	4
170	4
176	4



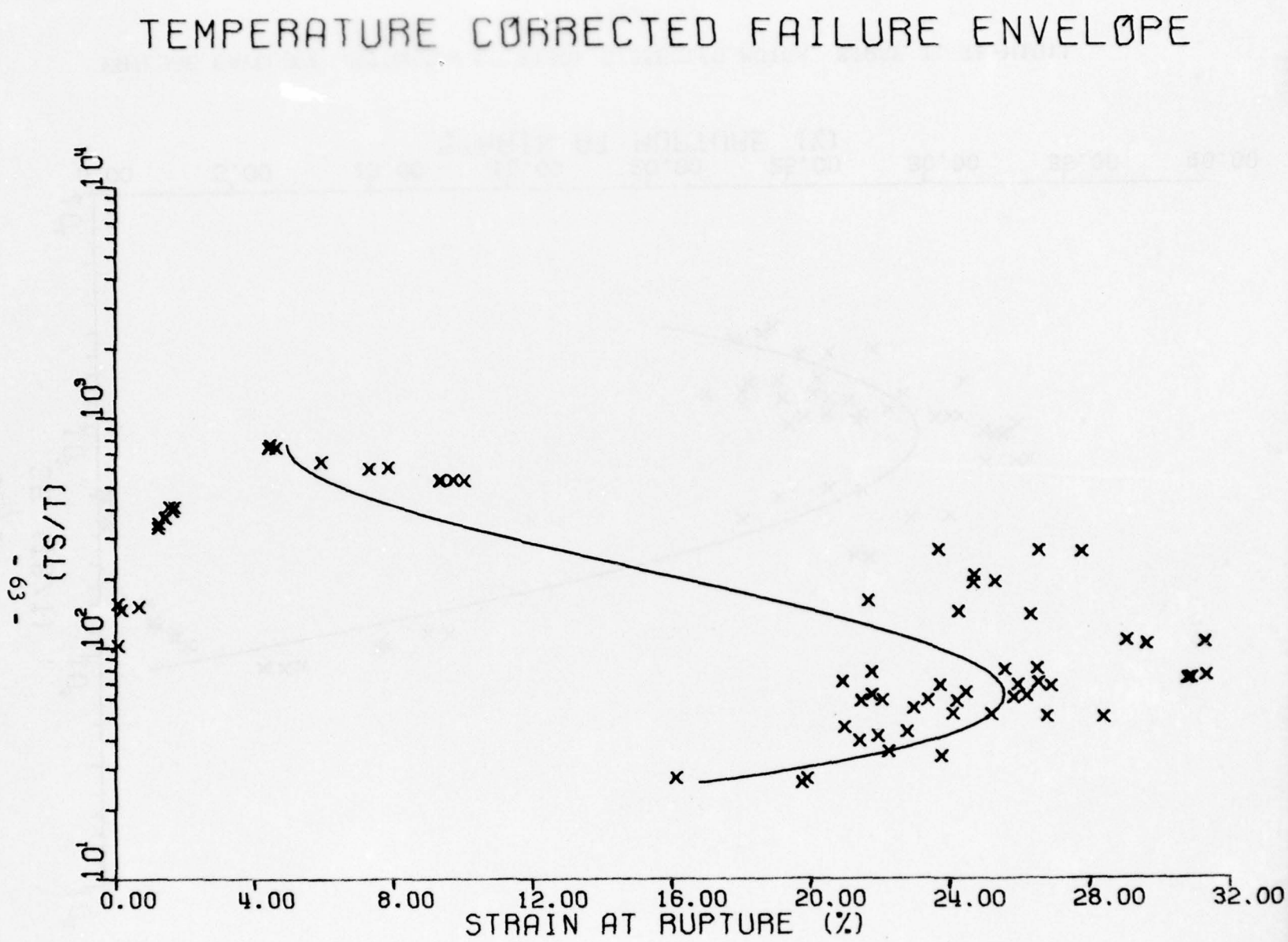
DISSECTED MTR, STAGE 1, TP-M1011, SOL GEL, CROSSLINK DENSITY

Figure 50



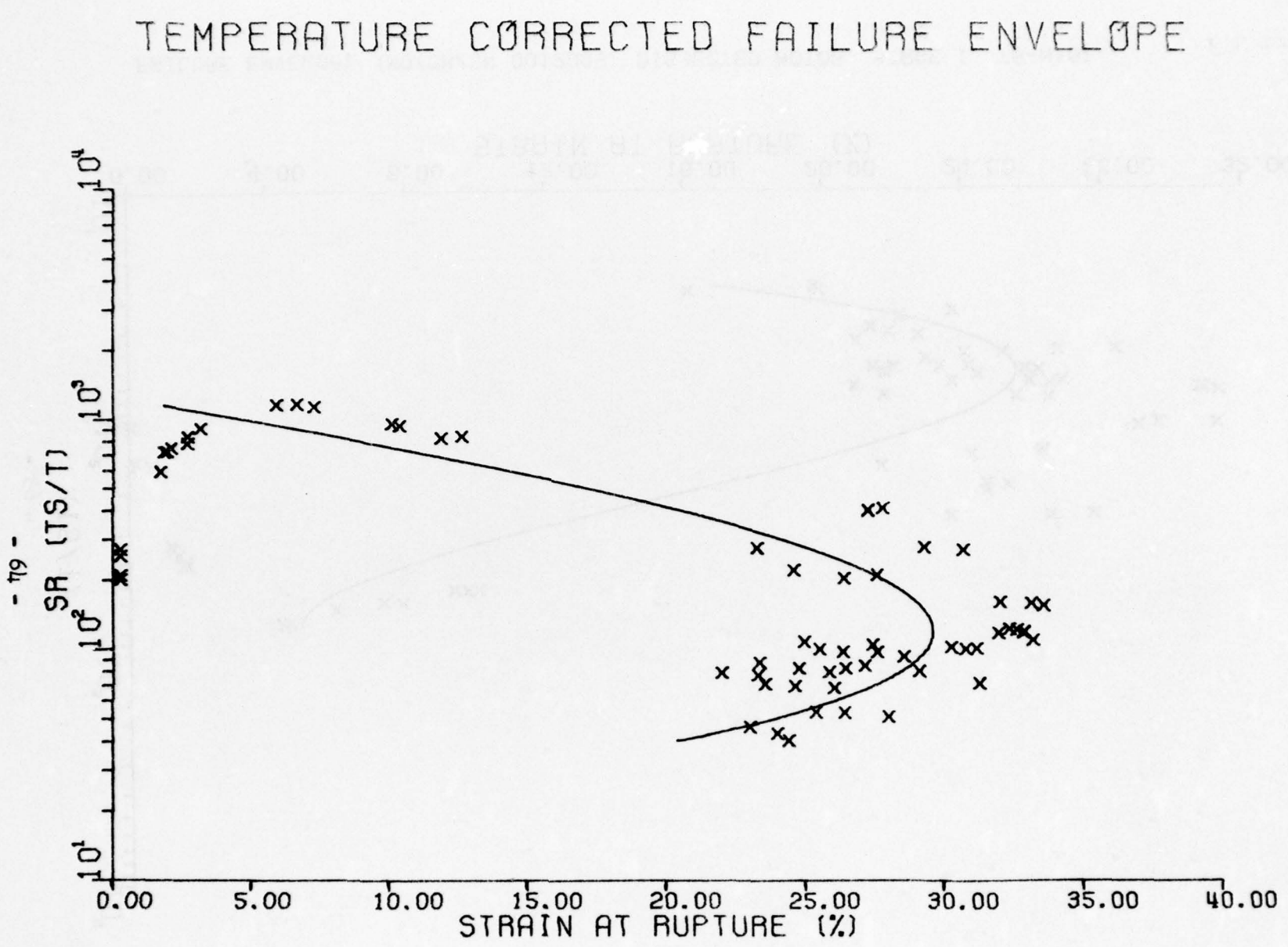
FAILURE ENVELOPE (MOTOR/SN STM-012) DISSECTED MOTOR, STAGE I, TP-H1011

Figure 51



FAILURE ENVELOPE (MOTOR/SN 0012099) DISSECTED MOTOR, STAGE I, TP-H1011

Figure 52



FAILURE ENVELOPE (MOTOR/SN 0012199) DISSECTED MOTOR, STAGE I, TP-H1011

Figure 53

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18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Solid Propellant
Minuteman

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Testing was performed to determine the useful shelf/service life for LGM-30 Stage I Rocket Motors. A three year storage program for propellant and components was started in May of 1961. This program was then extended to a ten year study and later continued indefinitely to assure that deterioration in motor physical characteristics could be detected in time to take some corrective actions before the weapon system performance deteriorated below an acceptable level.

(OVER)

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(Block 20 cont.)

This report covers only propellant data and limited case bond data. The mal-function of an environmental chamber and the inadvertant burning of motors during dissection destroyed component samples that had originally been part of this testing program. Dissection of selected motors in the future will provide samples for continued component testing. Test specimens for this reporting period were obtained from motors STM-012, 0012099, 0012199 and UP7775 block propellant.

The data from this test period are combined with data from previous testing and entered into the G085 computer for storage, analysis, and regression analysis. From the statistical analysis of all data tested to date, significant degradation of the propellant does not appear likely for at least two years past the oldest data point.

Future testing will be conducted on dissected motors.